EVALUATION OF JUVENILE SALMONID OUTMIGRATION AND SURVIVAL IN THE LOWER UMATILLA RIVER BASIN

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Umatilla River Outmigration and Survival Evaluation

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EXECUTIVE SUMMARY

This is the first year report of a multi-year project that monitors the outmigration and survival of hatchery and naturally produced juvenile salmonids in the lower Umatilla River. This project supplements and complements ongoing or completed fisheries projects in the Umatilla River basin. Knowledge gained on outmigration and survival will assist researchers and managers in adapting hatchery practices, flow enhancement strategies, canal operations, and supplementation and enhancement efforts for natural fish populations. This project also completed tasks related to evaluating juvenile salmonid passage at Three Mile Falls Dam and West Extension Canal.

Umatilla River Outmigration and Survival Evaluation

Objectives for FY 1995

1. Conduct trap feasibility studies and determine trapping efficiencies of collection facilities.
2. Determine migration performance, migration pattern, and migrant abundance of hatchery released spring and fall chinook salmon, coho salmon, and summer steelhead in the lower Umatilla River.
3. Determine migration performance, migration pattern, life history characteristics, and migrant abundance of naturally produced juvenile salmonids and summer steelhead within the lower Umatilla River.
4. Investigate relationships between river flow/temperature and migration performance and pattern of all species.
5. Conduct feasibility studies to estimate reach-specific survival of hatchery released spring and fall chinook salmon and summer steelhead in the lower Umatilla River.
6. Conduct feasibility studies to estimate survival of naturally produced juvenile salmonids from near Pendleton to the lower Umatilla River.
7. Evaluate cumulative injury to hatchery and natural juvenile salmonids emigrating through the lower Umatilla River.
8. Determine biological and environmental variables that may affect in-river survival for hatchery and natural juvenile salmonids.
9. Investigate the utility and feasibility of using PIT tags in the Umatilla River.

Accomplishments and Findings for FY 1995

We achieved most of our objectives in FY 1995. We sampled two lower river locations with our floating net trap (November - December 1994) and with the rotary-screw trap (January 1995). We sampled at Feed Canal during winter and at West Extension, Westland, and Maxwell canals during the spring and summer irrigation season. Monitoring extended through September 1995.

Trap efficiency tests were conducted with hatchery and wild salmonid species collected at the in-river sites and at Feed and West Extension canals. Quickest recaptures and most consistent efficiencies were obtained with subyearling chinook salmon (Oncorhynchus tshawytscha) at the in-river trap sites; trap efficiencies ranged from 11% to 39%. Many trap efficiency tests conducted at West Extension and Feed canals with yearling species resulted in zero recaptures and extended recapture periods (> 30 days), although most fish were recaptured within a day after release. Wild and hatchery subyearling spring chinook and fall chinook salmon had the highest mean trap efficiency estimates (> 24%); coho salmon (0. *kisutch*) and summer steelhead (0. *mykiss*) had the lowest (range 4% - 11%). Trapping efficiency of subyearling fall chinook salmon dropped from about 50% to 5% when canal diversion and attraction flows almost ceased at West Extension Canal. Few wild fish were recaptured. Diel movement of marked fish coincided with diel movement of unmarked fish of the same species.

We collected a total of 742,223 hatchery salmonids and 6,483 natural salmonids at all sites. Salmonids included hatchery and wild fall and spring chinook and coho salmon of yearling and subyearling sizes, and yearling summer steelhead. Subyearling spring chinook salmon dominated our catches in fall and winter; yearling spring and fall chinook salmon, coho salmon, and summer steelhead were dominant in spring; subyearling fall chinook salmon were dominant in summer with the wild subyearlings predominant in July. At West Extension Canal, we captured 40% of the yearling chinook salmon releases, over 25% of the yearling coho salmon releases, 12% of the summer steelhead releases, and only 3% of the subyearling fall chinook salmon releases. We collected scale samples for age analysis from 468 natural juvenile salmonids, mostly summer steelhead.

Brand groups of yearling spring chinook salmon from Umatilla Hatchery were recovered in similar proportions to each other, as were brand groups from Bonneville Hatchery. Branded groups of spring chinook salmon from Bonneville Hatchery released one month later (21 April) than Umatilla groups (13 March) were recaptured at a lo-fold higher rate. Most brand groups of subyearling fall chinook salmon from Umatilla Hatchery were collected in similar proportions to each other, but recovery of brand groups of summer steelhead was statistically disproportionate. Fin-clipped fish were recovered in similar proportions for summer steelhead (AD/ADLV) and subyearling spring chinook salmon released in the fall (RV/ADRV), but not for yearling spring chinook or subyearling fall chinook salmon.

Migration patterns were defined for all salmonid species collected at Feed and West Extension canals, including migration timing, magnitude, and duration. Migration of subyearling spring chinook salmon released in the fall lasted from mid-November to late February, with most movement in November and December. Coho salmon released on 21 February were first captured the next day at Feed Canal, traveling 13.3 miles/day. Peak capture (527 fish) was on 24 February. Coho salmon released in late March and early April peaked in number on 2 May (124,352 fish) at West Extension Canal and continued to be captured until mid-July. Peak capture of yearling spring chinook salmon released 13 March occurred the same day at Feed Canal (5,204 fish), traveling more than 50.8 miles/day. Within two weeks, most of these spring chinook salmon had moved out of the river. At West Extension Canal, most salmonid species migrated from late April to early May. Summer steelhead released on 11 April were captured the next day, traveling 39 miles/day. Peak capture for the 13 April second release was on 28 April (2,412 fish). Collection of steelhead continued into early June after the third release on 12 May. Yearling spring and fall chinook salmon released in mid-April reached peak collection on 26 April (29,495 fish) and continued to be captured into early June. Some groups of subyearling fall chinook salmon escaped from upriver acclimation ponds and were first captured on 16 May. Peak capture of fish released on 31 May was on 3 June (30,264 fish); migration rate was 37.3 miles/day for this group. Last capture was on 8 July.

Wild yearling spring chinook salmon were most active in their migration the first three weeks of April and peaked in number on 16 April (882 fish). Wild spring chinook were last captured in mid-May. First capture of wild subyearling fall chinook also occurred in mid-May; capture peaked on 2 July (11 fish). Wild summer steelhead peaked in number on 28 April (443 fish) and were last captured on 10 June. Their migration pattern was similar to hatchery summer steelhead. Wild coho salmon were captured intermittently from early April to early August with a peak collection (37 fish) on 29 April.

Most subyearling spring chinook salmon released in the fall migrated 3 hours after sunset (1600 hours) in November. In March, April, and May, diel patterns of movement generally were near the times of sunrise and sunset for most species. Within a day, different species had different specific times of peak movement. In June, subyearling fall chinook salmon migrated most at midday.

Condition of hatchery fish was impacted by bird predation, bacterial kidney disease, scale loss, and other injuries to the head, eyes, operculum, and body. Over time, condition of hatchery fish deteriorated more than wild fish. Hatchery summer steelhead had the most scale loss and bird marks. Mortality of hatchery yearling chinook salmon arriving at West Extension Canal increased to 3% as bacterial kidney disease became more prevalent. Hatchery subyearling fall chinook salmon mortality increased to 10% when water conditions (flow and temperature) deteriorated and disease (bacterial gill and *Ichthyophthirius*) increased from mid- to late June. Hatchery coho salmon were in better condition throughout their migration compared to other hatchery species. Wild spring chinook salmon and summer steelhead were infested with the parasite *Neascus metacecaria* (Black spot disease), particularly wild chinook salmon collected during the winter.

Wild and hatchery fish transitioned toward the smolt stage over time. Based on visual observation, coho salmon were mostly parr after release in February and were mostly smolts when peak numbers were collected in early May. Hatchery summer steelhead and subyearling fall chinook salmon were the most smolted after release. Wild summer steelhead gradually transitioned from parr status to smolt status from late March to early June.

Mean fork lengths for wild juvenile salmonids were significantly ($P <$ 0.001) smaller than hatchery fish of the same species. From December through March at Feed Canal, mean fork length was 87.8 mm for wild coho salmon, 100.8 mm for wild spring chinook salmon, and 141.9 mm for wild summer steelhead. From April to July at West Extension Canal, mean fork lengths were 113.1 mm for wild spring chinook salmon, 66.3 mm for wild coho salmon, 68.1 mm for wild fall chinook salmon, and 179 mm for wild summer steelhead. Collected fry of wild coho and fall chinook salmon were < 50 mm.

Survival estimates were primarily for fish migrating from their respective release points to lower river trap sites. We estimated a minimum survival of 2.6% (9,657 fish) for subyearling spring chinook salmon released in November, 66.6% (294,053 fish) for yearling spring chinook salmon released in March, and 9.2% (29,798 fish) for coho salmon released in February, based on intermittent sampling. During continuous sampling at West Extension Canal, abundance was overestimated for hatchery coho salmon, yearling spring and fall chinook salmon combined, and summer steelhead, compared to numbers released. Overestimation was probably due to bias in trap efficiency estimates. Abundance estimates of subyearling fall chinook salmon at RM 3 were complicated by trapping at RM 27.3 for transport, beginning 8 June. We estimated 420,608 subyearling fall chinook salmon migrated past RM 3, comprising a survival estimate of 17.7%. Including transported fish (approximately 96,000 fish), overall survival was 21%. Mean survival of subyearling fall chinook salmon from RM 32.5 to RM 3 (based on release-recapture of marked fish) was 40.8%. We estimated 73,696 wild spring chinook salmon and 54,361 wild summer steelhead migrated past RM 3. Small sample sizes for wild subyearling fall chinook and wild coho salmon precluded estimation of abundance. Lack of upriver marking of wild juvenile salmonids precluded our ability to estimate their survival. Mean survival indices by brand recovery were lower for summer steelhead (20.5%) than indicated by the abundance estimation method, but similar for subyearling fall chinook salmon (14.0%).

Flow in the Umatilla River peaked in early February (6,500 cfs at RM 3), declining to < 100 cfs in late summer. Mean river flows during April, May, and June at RM 3 were 877 cfs, 2,398 cfs, and 205 cfs, respectively. Water temperature fluctuated from a low of 33° F in January to a high of 76° F in July at RM 14. Mean water temperature at RM 3 increased from 51.3° F in March to 71.5° F in June. More fish were collected at RM 3 when river flows were increasing and water temperatures were decreasing. However, there was little linear correlation between total fish collection and river flow ($r = 0.24$) or water temperature ($r = -0.22$) over the migration season .

Gulls (*Larus* spp.) and great blue herons (*Ardea* spp.) were the major avian predators. Gulls represented over 70% of the birds observed at canal sampling sites and were most active during the day. Herons were most active in feeding at night or early morning at the canal facilities. Northern squawfish (*Ptychocheilus* oregonensis) was the major piscivorous fish species captured. Large-sized northern squawfish (> 220 mm) comprised 21% of the resident fish collected at RM 3 in August.

Resident fish collected included redside shiners (*Richardsonius balteatus*), chiselmouth (*Acrocheilus alutaceus*), bridgelip and largescale suckers (*Catostomus columbianus*, C. *macrochelius*) largemouth and smallmouth bass (*Micropterus salmoides*, *M. dolomieu*), speckled dace (*Rhinichthys osculus*), bullhead (*Ictalurus spp.*), white crappie (*Pomoxis annularis*), peamouth (*Mylocheilus caurinus*), yellow perch (*Perca flavescens*), whitefish (*Coregonus sp.*), sunfish (*Lepomis cyanellus*), and Pacific lamprey (*Entosphenus tridentatus*). Twenty-four Pacific lamprey were caught at RM 3, ranging in length from 50 mm to 600 mm.

We investigated costs of PIT tag detectors and equipment and developed a proposal to use 134.2 kHz PIT tags in the Umatilla basin in 1997. Use of PIT tags would enhance outmigration monitoring and survival estimation.

Management Implications and Recommendations

1. High water temperature and reduction of river flow from irrigation withdrawals from late spring to midsummer create stressful conditions for later outmigrating wild and hatchery fall chinook salmon subyearlings. Mortality and incidence of disease increases at the Westland trap as summer progresses. Transporting of already stressed fish undoubtedly impacts their survival further. We recommend longer-term water releases from McKay reservoir in June to move hatchery and wild subyearlings out of the system prior to transport. This may require maximizing water exchanges with upriver canals.

2. Sustained fish movement is not positively correlated with sustained high flows. Therefore, we recommend pulsing water releases from McKay reservoir to increase the effectiveness of moving fish out.

3. Subyearling fall chinook salmon traveling through Maxwell Canal to the bypass can be killed by chemical control of weeds in the canal forebay. We suggest monitoring fish presence in the canal and facility prior to herbicidal application, or manual removal of weeds.

4. Birds undoubtedly prey on fish. To assist in fish survival, we recommend not operating bypass facility lights at night which may attract herons and other birds.

5. May releases of summer steelhead (graded smalls) produced a lower survival index, based on brand recovery, than the earlier releases in April (large, mediums). We recommend releasing these fish earlier to increase their survival potential. This may require alteration of the hatchery rearing program for steelhead smalls to attain an adequate size at release in late April.

6. Post-release subyearling chinook salmon that were pathologically examined were infected with *Ich* and bacterial gill disease. To better understand fish health in-river, and its effects on survival, we recommend an increase in routine fish health monitoring on collected hatchery and wild salmonids, particularly with fish that show signs of stress, disease, or parasitic infections.

Objectives for FY 1995

1. Determine passage efficiency of juvenile salmonids at West Extension Canal under various canal operations and river flows.

2. Determine effectiveness of passage routes at West Extension Canal and Three Mile Falls Dam in providing safe and quick passage for juvenile salmonids.

3. Prepare a final completion report for the juvenile salmonid passage evaluation study.

Accomplishments and Findings for FY 1995

We achieved most of our objectives in 1995. We were unable to successfully monitor smolt passage at the fish exit gate diffuser at Three Mile Falls Dam (Objective 2) due to camera damage. However, we determined that video monitoring is feasible at the specified location.

Canal operations affected fish passage into and through the canal bypass at West Extension Canal, diversion rate and river flow affected some species more than others, and canal flow had little affect on fish passage ($r = 0.13$). When Phase I pump exchange of water into the canal was initated in late May and the river-return drain pipe was closed at the bypass facility, trap efficiencies for subyearling fall chinook salmon dropped from near 50% to below 5% within a day. The linear correlation between rate of canal diversion and daily estimates of trap efficiency for coho salmon and subyearling fall chinook salmon were significant and higher ($r < 0.50$, $P < 0.04$) than that for yearling chinook salmon ($r = 0.28$) and summer steelhead ($r = -0.43$). River flow exceeding 2,000 cfs greatly reduced trap efficiencies for all species.

Approach water velocities at the West Extension Canal traveling screen met criteria for smolts, but not completely for fry under normal operating conditions. When the river-return drain pipe was opened 40%, velocity criteria for smolts and fry was exceeded, especially along the upstream transect of the screen and at water depths of 20% and 80%.

Sweep velocities at the traveling screen met criteria during all pump and drain pipe operations tested, and generally decreased from upstream to downstream locations. Back-eddy turbulence at the interface of the 5-cfs orifice plate and the traveling screen increased with screen flow.

Approach velocity at the drum screens was negligible when canal checkgates were closed, increasing to 0.12 fps with a 52 cfs canal flow. Under normal maximum flow (120 cfs), approach criteria would still be fully met for smolts (≤ 0.8 fps), but one-third of the sampling locations would not meet criteria for fry (≤ 0.4 fps).

Mean sweep velocity at the drum screens (0.51 fps) was increased with a 20% river-return pipe opening compared to velocity resulting from a one-pump operation (0.16 fps) when canal checkgates were closed. Sweep velocities were uniform across the drum screens during canal flow, but were not when canal flows ceased.

Water velocities that attract fish into and through the bypass facility were greater when the river-return pipe was open than when the pumpback pumps were operating. The affect of operating the river-return drain pipe was most noticable at the canal trashracks and headgates; velocities were three times the water velocities during pump operations. Water velocities between a two-pump operation and a 20% drain pipe opening were nearly equal.

Direction of flow approaching the lower auxiliary water diffuser at Three Mile Falls Dam was highly variable. Sweep velocities exceeded 1 fps on the east end of the diffuser panel. Adjacent flow from the passage section entering into the fish entrance pool caused parallel flow at the diffuser. Maximum approach and sweep velocities were 1.90 fps and 1.61. fps, respectively.

We completed a draft of the Passage Study completion report in October 1996. We presented results on screening efficiency, fish injury, fish travel time, and water velocities at passage facilities on the Umatilla River.

Management Implications and Recommendations

1. Passage efficiency at West Extension Canal for migrating salmonids in late spring decreased dramatically when Phase I pumping reduced water diversion through the canal and attraction flow at the canal headgates. When trapping fish during Phase I exchange, the river-return drain pipe should be operated 20%-open to maximize water diversion and attraction flow for increasing passage efficiency. When not trapping fish, a full 25-cfs bypass flow should be maintained to efficiently bypass fish.

2. The bypass at West Extension Canal is a more effective passage route for juvenile salmonids than the east-bank ladder at Three Mile Falls Dam. Past research has shown that diffusers in the fish ladder delay and injure fish. When necessary, auxiliary flow at the fish ladder should be reduced to provide sufficient flow (25 cfs) through the bypass.

2. Attraction of adult salmonids to flow from the river-return drain pipe is a problem, especially during low river flows. Corrective measures such as a fish barrier or flow dissipation should be considered.

3. All screening velocity criteria were generally met under normal operating conditions. However, operation of the river-return pipe at openings greater than 20% can create unfavorable hydraulic conditions for fish. We recommend that at no time should the river-return pipe be opened more than 20%.

4. Back-eddy turbulence at the downstream end of the traveling screen existed under all operating conditions, but increased as flow increased through the traveling screen. We recommend monitoring fish behavior at the traveling screen with underwater video. If possible, removal of the orifice plate should be considered to reduce back-eddy turbulence.

5. **Velocities through diffusers in the auxiliary water portion of the adult fish ladder were turbulent and in many locations exceeded design criteria. Although we do not recommend any changes, we recommend fishery managers be aware of the existing hydraulic conditions, that may present a potential hazard to juvenile salmonids, when assessing the suitability of the ladder for juvenile fish passage.**

REPORT A

Umatilla River Outmigration and Survival Evaluation

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UMATILLA RIVER OUTMIGRATION AND SURVIVAL EVALUATION

INTRODUCTION

Reintroduction of chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) and enhancement of summer steelhead (*O. mykiss*) populations in the Umatilla River was initiated in the early and mid 1980's (CTUIR and ODFW 1989). Measures to rehabilitate the fishery and improve flows in the Umatilla River are addressed in the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (NPPC 1987). These include habitat improvement, hatchery production, holding and acclimation facilities, flow enhancement, passage improvement, and natural production enhancement. Detailed scope and nature of the habitat, flow, passage, and natural production projects are in The Umatilla River Basin Fisheries Restoration Plan (CTUIR 1984, Boyce 1986). The Umatilla Hatchery Master Plan (CTUIR and ODFW 1990) provides the framework for hatchery production and evaluation activities. Evaluation of juvenile salmonid outmigration and survival in the lower Umatilla River basin is necessary to determine, in part, the success of these projects and the overall effectiveness of the rehabilitation plan. This project answers questions regarding salmon migration in the Umatilla River basin and supplements and complements ongoing or completed evaluations of specific rehabilitation projects. A multitude of agencies and entities cooperate, coordinate, and exchange information in the Umatilla basin, including the U.S. Bureau of Reclamation (USBR), the Bonneville Power Administration (BPA), National Marine Fisheries Service (NMFS), Oregon Water Resources Department (OWRD), the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and three local irrigation districts (West Extension, Hermiston, and Stanfield-Westland). The Umatilla River Operations Group and the Umatilla Monitoring and Evaluation Oversight Committee coordinate research and management in the Umatilla River basin.

A critical uncertainty is whether juvenile fish, hatchery or natural, are surviving and successfully migrating out of the Umatilla River basin. Although smolt-to-adult survival is being assessed through the Umatilla Hatchery Monitoring and Evaluation Project (Keefe et al. 1993, 1994, Hayes et al. 1995, 1996), results are broad in scope and reliant on adult returns which precludes final data analysis until after the year 2000. Potential factors determining survival in the Umatilla basin include loss of juvenile salmon through in-river predation, cumulative effects of passage through a multitude of passage facilties at irrigation diversion dams, effects of canal operations and poor river conditions on fish health, and effects related to hatchery rearing and release strategies.

To evaluate the effectiveness of specific hatchery practices at Umatilla Hatchery, information is needed on migration success and performance of different rearing and release strategies within the Umatilla River. Strategies for rearing include use of standard Oregon raceways and oxygenated Michigan raceways. Release strategies include yearling versus subyearling production and separate releases of graded summer steelhead.

A complex of issues related to water use in the Umatilla River is associated with fisheries rehabilitation. Providing water to irrigators and flows for anadromous fish is a desired goal of the Umatilla Basin Project (USBR 1988). The understanding of fish needs for passage, rearing, and survival, and species-specific migration characteristics are critical considerations in canal operations, water release strategies, and flow enhancement strategies in the Umatilla basin (USBR 1988; USBR and BPA 1989).

The Confederated Tribes of the Umatilla Indian Reservation is attempting to investigate the natural production potential of each race or species of salmonid in the Umatilla River basin and the effects of hatchery steelhead supplementation on native steelhead (CTUIR 1994, Contor et al. 1995, 1996). Addressing these critical uncertainties has required the estimation and determination of survival, life history characteristics, distribution, composition, abundance, and production capacity of naturally-produced juvenile and adult salmonids in the Umatilla River basin. Monitoring in the lower river is crucial for determining movement patterns, arrival times, and lower river abundance of naturally-produced salmonids originating in the upper river.

The use of PIT tags in the mainstem Columbia and Snake rivers has been an integral part of recent survival studies (Iwamoto et al. 1994, Muir et al. 1995, 1996). Installation of future PIT-tag detectors at John Day Dam will improve estimates of survival and migration performance of Umatilla River smolts (hatchery and natural). We plan to investigate the feasibility of PIT tags to monitor the outmigration and survival of Umatilla River juvenile salmonids.

The goal of the Outmigration and Survival Study is to evaluate the outmigration and estimate survival of juvenile salmonids in the lower Umatilla River basin. Specific objectives toward meeting this goal for the 1994-1995 project period were:

1. Conduct feasibility studies with traps and determine trapping efficiencies of collection facilities.

2. Determine migration performance, migration pattern, and migrant abundance of hatchery-released spring and fall chinook salmon and summer steelhead in the lower Umatilla River.

3. Determine migration performance and pattern, life history characteristics, and migrant abundance of naturally-produced juvenile salmonids and summer steelhead within the lower Umatilla River.

4. Investigate relationships between river flow/temperature and migration performance and pattern.

5. Conduct feasibility studies to estimate reach-specific survival of hatchery-released spring and fall chinook salmon and summer steelhead in the lower Umatilla River.

6. Conduct feasibility studies to estimate survival of naturally-produced juvenile salmonids from near Pendleton to the lower Umatilla River.

7. Evaluate cumulative injury to hatchery juvenile salmonids migrating through the lower Umatilla River.

8. Determine biological and environmental variables that may affect in-river survival for hatchery juvenile salmonids.

9. Investigate the utility and feasibility of using PIT-tags in the Umatilla River.

In this report, we describe our first year activities and findings for the Umatilla River Outmigration and Survival Study from 1 October 1994 to 30 September 1995. We present information from outmigration monitoring, including species and origin of fish collected, lengths, fish condition, smoltification levels, brands and fin clips observed, diel movement, migration patterns, and migration performance. We also present trapping efficiencies, estimations of migrant abundance and survival, observations of predators and resident fish, and environmental conditions during the spring outmigration. We discuss the feasibility of PIT tag use in the study program.

STUDY SITES

Outmigration data was collected from six sampling sites during the 1994-95 field season. These sites included two in-river locations below Three Mile Falls Dam and four irrigation canal screening facilities (Figure 1). In addition, fish were collected for survival study marking at a fifth canal screening facility.

In-river sites were selected based on appropriate water depth and velocity, trap accessibility, suitable trap anchoring points, and trap pull-out availability. These considerations were critical for proper deployment and use of our in-river traps.

The first in-river sampling site was at rivermile (RM) 0.5 behind Umatilla High School in the town of Umatilla (Figure 1). We used a floating net trap at this location in November 1994. The site was a low gradlent, riffle-glide habitat with a cobble bed. The main channel where we sampled was on the south bank of the river and was approximately 30-feet wide. River depth within the channel was approximately 2.5 ft to 3.5 ft during the sampling period. Total river width was approximately 100 ft. We used shoreline trees and river boulders as anchoring for trap rigging, Trap efficiency releases for this site were made at Brownell Dam (RM 1.2) on the east bank of the river (Figure 1).

The second in-river site was located upriver at RM 1.8 (Figure 1). River flow split into two main bedrock channels at this site. Total river width was approximately 220 ft. In January 1995, we used an 8-foot-diameter rotary-screw trap in the west channel. Channel depth was approximately 4 1/2 ft and width was approximately 40 ft, bounded by solid bedrock. We anchored the trap to bedrock cliffs on the west and east river banks to sufficiently clear the water during high flow. A midriver island below the west channel was used to harbor the trap in high water and aided trap access. Trap efficiency releases for this site were made upstream below Three Mile Falls Dam (RM 3.0) on the west bank of the river (Figure 1).

During other months fish were sampled at screening facilities at Feed, West Extension, Maxwell, and Westland canals (Figures 2 and 3). Trap efficiency tests were performed only at West Extension and Feed canals. Fish for survival study marking were captured at Furnish Canal (Figure 1).

These canal screening facilities exclude juvenile fish from the respective irrigation canals and return the fish to the river via a bypass. All screening facilities are operated in accordance with criteria established by the National Marine Fisheries Service (NMFS 1989, 1990). Features common to all canal screen sites include 1) canal headgates, checkgates, and a bypass channel weir for regulating canal withdrawals, headworks water elevation, and bypass flow, respectively; 2) rotary drum screens and a bypass channel, downwell, pipe, and outlet structure to screen fish from the canal and return them to the river; and 3) trash racks to intercept debris. Flow into the canal and bypass channel is usually dependent on river flow and irrigation needs. Features unique to some canals include 1) a wasteway channel to dampen headworks fluctuations (Westland, Furnish, and Maxwell canals); 2) pumps to increase water velocity at the bypass channel entrance (Westland and West Extension canals); and, 3) traveling screens to exclude fish and debris from these pumps (Westland and West Extension canals). We installed inclined plane traps in the bypasses at Feed, Maxwell, and Furnish canals to sample fish. Permanent fish trapping facilities sampled fish at Westland and West Extension canals.

We sampled at the West Extension Irrigation District Canal from late March through September 1995 (Figure 2). West Extension Canal is located on the west bank at Three Mile Falls Dam at RM 3.0 (Figure 1). The canal generally operates from late March through mid-October. Distance from the headgates to the bypass channel is approximately 130 ft. The canal passes a maximum nominal flow of 180 cfs through four rotary drum screens and from 5 cfs to 25 cfs through the bypass channel.

The West Extension Canal juvenile fish trapping facility was originally built to trap fish for transport to the lower river. In 1990, the facility was modified to sample and bypass fish (Knapp and Ward 1990). The facility includes two primary pumpback pumps which each return 10-cfs of bypass water to the canal, a 6-ft-wide by 14.5-ft-high traveling water screen which excludes juvenile fish from the pumpback flow, a spray water system that cleans the traveling screen of debris, a 2-ft-wide fish bypass channel, and a 3-ft-wide by 13-ft-long by 18-ft-deep downwell (Figure 2). A 24-inch river-return drain pipe located in the pumpback bay also evacuates water from the bay to the river. A restrictive orifice plate immediately downstream of the traveling screen reduces bypass flow to 5 cfs during trapping. An inclined screen installed in the bypass channel between the orifice plate and the bypass weir guides fish into a fish separator and transfer flume. The transfer flume includes an air-operated gate that directs fish into either a sampling tank or a 6-inch bypass line. A timer adjusts the gate position at desired intervals to permit subsampling of large numbers of moving fish. The below-ground sampling area contains two tanks (sampling and recovery) with an auxiliary water supply system, and piping to return fish to the downwell. The 24-inch-diameter, 240-ft-long fish return pipe carries fish from the bypass downwell to the bypass outfall above the river.

Three different release sites were used for collection efficiency tests at West Extension Canal (Figure 1). The first site was located on the west bank approximately 1/4 mile upriver from the facility. The second release site was located at RM 4.7 also on the west bank of the river. The third release site was located at the Hermiston Wastewater Treatment plant (RM 5.0) on the east bank of the river (Figure 1). The second and third release sites were far enough upstream to potentially improve fish dispersal throughout the river.

We sampled at Feed Canal intermittently from December 1994 through March 1995 (Figure 2). Feed Canal is adjacent to the north end of Feed Canal Dam at RM 29.2 (Figure 1). The canal delivers irrigation storage water to Cold Springs Reservoir and generally operates from mid-November through mid-May. Distance from the headgates to the bypass channel is approximately 695 ft. This facility will pass a maximum nominal flow of 245 cfs through 10 rotary drum screens and from 5.5 cfs to 18 cfs through the bypass channel. Bypass flow is regulated by a hand-operated weir. The bypass downwell is L-shaped and measures 9 ft in length for each section, 3 ft in width, and 8 ft in depth. The downwell opens to a 30-inch-diameter, 300-ft-long bypass pipe which terminates in a partially submerged outlet structure on the river bank.

Two release sites on the east bank of the river were used for collection efficiency tests at Feed Canal. The first site was approximately I/4 mile upstream of the canal entrance at RM 29.5. A second site was farther upstream of the canal entrance at RM 31.2 (Figure 1). This site was accessible by truck and provided for greater dispersal of fish through the river due to the increased distance from the canal.

We sampled at Westland Canal in June 1995 during juvenile fish trap and haul operations (Figure 3). Westland Canal is located at Westland Dam at RM 27.3 (Figure 1). The canal passes a maximum nominal flow of 330 cfs through 10 drum screens from late February through November. Distance from the headgates to the bypass channel is approximately 330 ft. Unique components of Westland Canal include two traveling screens and two 9-cfs pumps, a fish separator, and a juvenile fish holding pond.

Westland Canal juvenile fish bypass facility operates in either a bypass or trapping mode. Fish are trapped for transport when river flow is expected to drop below 150 cfs. During fish bypass operations, bypass flow varies from approximately 10 cfs to a maximum bypass flow of 26 cfs. Fish are returned to the river via a 17-inch-diameter, 700-ft-long bypass pipe leading to a submerged outlet in the river channel. In a trapping mode, flow to the downwell is stopped, 6 cfs of flow is passed into the pumpback bay, and a 4-cfs flow is passed into the juvenile holding pond. During trapping operations, fish are collected and held in the 10-ft-wide, 60-ft-long, and 5-ft-deep pond.

We sampled at Maxwell Canal in late June 1995 (Figure 3). Maxwell Canal is located at Maxwell Dam (RM 14.8) on the north bank of the river (Figure 1). The canal passes a maximum nominal flow of 60 cfs through three drum screens and operates from mid-April through late August. The canal headgates are located 1.5 miles upstream of the screening facility. The bypass channel operates at either a 9-cfs or a 2-cfs bypass flow at high and low river flows, respectively. Flow is controlled by weir boards instead of gates. The bypass chamber measures 4-ft wide by 11-ft long by 9-ft deep. A 24-inch-diameter, 230-ft-long bypass pipe carries fish to a 2-ft-wide by 3-ft-high outlet chute located on the north bank of the river.

We conducted survival test marking at Furnish Canal (RM 32.5) in early June 1995 (Figure 1). The canal generally operates from mid-March to mid-October.

METHODS

Migrant Traps

We collected fish in the lower river at Umatilla with a floating net trap (Cameron et al. 1994) . The 20-ft-long net tapered from a 5-ft-square mouth, to a 16-inch-diameter circle affixed to a floating livebox (Figure 4). The net and livebox were made with 3/16-inch knotless nylon netting. The 5-ft-square net mouth frame was attached to pontoon floats supported by a wooden frame. A swivel-type attachment of the net mouth frame to the pontoons aided deployment and transport of the trap.

The trapezoidal livebox was 55-inches long, 36-inches wide, and 28-inches high at the front and 53-inches wide by 40-inches high at the back. Netting completely covered the box which was supported by a polyvinyl-chloride (PVC) pipe frame.

Interior baffles reduced livebox velocities, improving holding conditions for fish. The baffles were made up of 4-inch-diameter PVC pipe cut into 2-ft-long sections and cut in half longitudinally. Pipe sections were mounted with the curved side facing upstream inside a l-inch-diameter PVC pipe frame which was attached to the bottom of the livebox interior. Baffles were angled towards the water flow by adjusting the length of a hook and chain connection from the baffle frame top to the front of the livebox.

We used a rotary-screw trap to collect fish in the lower river at RM 1.8 (Figure 5). The screw trap consisted of a 8-ft-diameter, 9-ft-long trapping cone, tapering to 2-ft in diameter at the downstream end. The perforated trapping cone housed an internal screw which rotated in the current, trapping fish. The trap sampled 23.1 square ft. The rear of the cone was attached to a 3-ft-long by 5-ft-wide, 12.8 ft^2 livebox containing a rear rotating drum screen to remove small debris. The cone and livebox assembly was mounted between two, 22.5-ft-long aluminum pontoons. Cabling of the cone frame to a small winch on the starboard pontoon allowed the cone to be raised or lowered. Eyebolts welded to the front of each pontoon were used for cable attachment. Railings were installed along the pontoons for safety.

To secure the trap in the river, we used rock cliffs as anchoring points for the cabling system. We drilled into the bedrock or constructed concrete blocks for installation of anchoring eyebolts. Trap cables were attached to these eyebolts (Figure 5).

A single cable, spanning 220 ft across the river, was used as the main support line. A 2-ton come-a-long was used to stretch the main line; heavy-duty turnbuckles attached to each cable end further tightened it. A cable pulley line was threaded through pulleys on each bank and connected to a master link at midriver. A pulley attached to the master link and threaded over the main line allowed the main line to bear most of the trap weight and permitted side-to-side movement of the trap via the pulley line. We used the come-a-long to move the pulley line. A cable trap line was routed from the trap, through another pulley at the master link, to a winch on the east bank. We used the winch to control upstream and downstream movement of the trap. The cabling system was designed for one-person operation. We accessed the trap by wading, dingy, or float tube, depending on flow.

We used inclined plane traps to collect fish at Feed, Maxwell, and Furnish canals (Cameron et al. 1994). Each trap was designed to specifically fit into the bypass channel of each facility and eliminate bypass flow for safe fish collection at a terminal livebox (Figure 4). Trap walls were solid 3/16-inch aluminum sheeting; trap floors were 1/8-inch aluminum perforated plate with 1/8-inch staggered holes (40% open). Each trap floor was supported underneath by longitudinal sections of 1-inch aluminum angle irons welded to 2-inch aluminum crosspieces.

A pivot rod front entrance assembly permitted leverage capabilities for adjusting water flow to a terminal, perforated livebox with an average capacity of 30 gallons. Lifting brackets welded onto the side walls and a front entrance lifting eye allowed the trap to be raised and lowered with chain hoists.

A permanent fish collection facility collected fish at West Extension Canal (Figure 6). The 100-ft^3 sampling tank was equipped with a crowder, divider, and lifting basket (Knapp and Ward 1990). Fish were crowded into the front half of the tank and isolated from incoming fish by lowering the divider. The lift basket could be raised to remove the crowded fish. Mylar mesh covers over the tank prevented escape of fish. When large numbers of fish moved into the facility, we subsampled them at various sampling rates, bypassing remaining fish through the bypass line. When the sample tank was overloaded with fish, we subsampled them and net carried the remaining fish to the bypass system.

Trap Efficiencies

Trap efficiencies were used to expand the catch of juvenile fish for an estimate of migrant abundance. We determined efficiencies for each trap by marking a known number of fish (M), releasing these fish upstream of the trap or collection facility, and recapturing them in the trap or bypass facility (m) over the duration of the collection period. Numerous releases were made for a species of fish to obtain mean and weighted trap efficiency estimates. The ratio of total fish recaptured to total fish released over the entire trapping period provided a weighted estimate of trapping efficiency for that period (TE = m/M). Mean efficiencies were based on daily trap efficiencies. Abundance estimates were derived from weighted trap efficiency estimates.

We attempted to mark at least 50 fish from the most dominant fish species in the collection; number of fish marked was usually proportional to number of fish collected which "weighted" the trap efficiency estimates. For trap efficiency tests, we used unmarked and unbranded hatchery and wild fish from the trap or bypass facility.

For marking test fish, we injected them with approximately 0.1 ml of acrylic paint using a 3-cc disposable syringe equipped with a 26-gauge intradermal needle. Eighty unique marks were possible using five paint colors and 16 body locations. We marked the ventral surface of the fish near fin locations with blue, red, orange, purple, or green paint. At canal facilities and in the lower river, we marked fish throughout the daily sampling period and held them for release the next day. Marked fish were held in net pens or a circular tank. Releases were generally made the following morning during 24-hour sampling or at the beginning of the work shift during 8-hour sampling. At the rotary-screw trap, fish were released as soon as possible after marking was completed.

We transported fish to release sites in 5-gal buckets, 30-gal containers, or a 250-gal slip tank, depending on the number of fish and distance to release site, Release site locations are described in STUDY SITES. Fish were released directly into the river from either the 5-gal or 30-gal containers. When using the slip tank, we released fish from the tank and into the river via a 6-inch flex hose connected to a 6-inch PVC pipe. Fish were held and transported at densities of less than one pound per two cubic feet of water. The slip tank was aerated with a pumped water circulation system.

Outmigration Monitoring

Collection

Hourly sample data collected at the West Extension Canal was expanded to account for sampling rates less than 100% and for less than full hour collections by dividing by the sample rate and proportion of the hour sampled, respectively. Data for whole hours not sampled within a 24-hour period were interpolated by multiplying the mean count of each fish species from sampled hours preceding and following unsampled hours by the number of hours not sampled

$$N_u = (N_1 + N_2)/2 \times h_u$$

where N_u is the estimated number of fish per species during the unsampled period; N_1 and N2 are the numbers of fish per species in the previous and following sampled hours, respectively; and h_u is the number of hours not sampled.

Twentyfour-hour collections at Feed Canal were also expanded for less than full hour collections. Daily collections at the rotary trap were generally for a 24-hour period; traps were checked once per day. When sampling for an 8-hour period at Feed Canal, Maxwell Canal, or in the lower river with the floating net trap, monitoring usually occurred during the period of peak movement in the day or evening. Data was expanded for less than full hour collections at Feed and Maxwell canals only.

Juvenile fish were anesthetized in tricaine methanesulfonate (MS-222) before examination. Fish were identified to species and origin (hatchery or wild) and counted. Hatchery fish (chinook salmon and summer steelhead) were differentiated from natural fish by the absence of either adipose or ventral fins. However, yearling spring and fall chinook salmon could not be differentiated because each species had the same ventral clip. Only 6% of the hatchery coho salmon were adipose clipped and coded wire tagged; otherwise, they were not clipped and could only be differentiated from wild fish based on size. Coho salmon < 100 mm in length were considered to be naturally produced. All fish were examined for freeze brands, fin clips, and trap efficiency marks.

Juvenile salmonids were sampled during trapping and hauling at Westland Canal during low river flow in June. Our sampling efforts were coordinated with CTUIR to ensure fish were sampled every day. Fish in the holding pond were crowded towards one end to facilitate loading and sampling. We initially netted fish from the crowded section in three different locations (left, middle, right) within the top and bottom of the water column to obtain a representative sample. Later, we sampled the center of the water column at the middle, left, and right. We examined species composition among the different sampling locations to determine if a bias existed in standard collection.

Fish were processed by the same procedures being used by CTUIR biologists. Net samples of fish were weighed and processed to identify and enumerate fish species and examine salmonids for marks and condition. We determined total species composition of combined samples and the number of each fish species per pound of fish transported.

Scale samples were collected from wild summer steelhead and wild coho salmon to determine their age and growth characteristics. Scales were collected above the lateral line and immediately anterior of an imaginary line from the posterior end of the dorsal fin to the anterior end of the anal fin. Scales were read by CTUIR biologists.

Brands

We documented most brands present on fish collected at our traps. Hatchery yearling spring chinook salmon, subyearling fall chinook salmon, and summer steelhead were branded, based on hatchery (Umatilla or Bonneville) and pond of rearing (Oregon or Michigan). We used brand recovery information to derive an additional index of survival. We computed the proportion of branded fish collected, per branded species, of the total readable brands released. We also expanded each brand group by estimates of weighted trap efficiency to estimate total brand abundance at the recovery site.

Fin Clips

We examined a portion of hatchery fish for fin clips. All spring chinook and fall chinook salmon were right-ventral (RV) clipped. Salmon with coded-wire tags were also adipose (AD) clipped. All summer steelhead were AD clipped. Steelhead with coded wire tags were left-ventral (LV) clipped. We determined the percent recovery of each clip for each species to ascertain survival differences between clips.

Migration

We described migration characteristics for each race or species of hatchery release by determining arrival time and migration rate to trap sites and migration timing. We also defined the duration of each species' outmigration and its magnitude with respect to date. Arrival time was the day of first capture after upriver release. Migration rate was the number of miles traveled by a group of fish (initial captures) per unit of time (day) subsequent to release. Migration timing was the cumulative percent capture of a fish species over time. Median capture was the day of 50% cumulative capture. Migration duration was the overall length of time from first to last capture. Migration peaks within the entire outmigration were determined by summation of hourly counts for a daily total. We also depicted migration magnitude and duration of species-specific brand groups. We used expanded and interpolated data in our analysis of migration.

For natural fish, we determined most of the above migration parameters. We recorded the first catch of a species or life stage. We also collected natural fish that were fin clipped at upriver trapping sites to determine movement.

Diel Movement

We used collection data from 24-hour sampling to define fish movement with respect to time of day. We assessed diel patterns of hatchery and wild fish species and compared these patterns with times of sunrise and sunset.

Smolt Index

A portion of hatchery fish were examined for indices of smoltification. We viewed the side of the fish to judge smoltification indices to differentiate parr from actively migrating smolts. These indices were classified as "P" for fish with visible parr marks, "I" for an intermediate phase showing silvery color but also residual parr marks, and "S" for silvery coloration. We also used these indices with natural fish to determine their stage of development.

Condition

A portion of hatchery and natural fish were examined for scale loss and other injuries to determine overall condition through time. We determined scale loss following criteria used by the Umatilla Hatchery Monitoring and Evaluation study (Keefe et al. 1994). We recorded fish condition as "good" if the cumulative scale loss was less than 3% per side of the body. If cumulative scale loss exceeded 3% on either side of the body, but was less than 20%, we listed the side(s) as "partially descaled". Sides that had a cumulative scale loss equal to or greater than 20% were "descaled". We also examined fish for external parasites and injuries to the head, eyes, gills, body, and tail. We noted fungal infections, indications of bacterial kidney disease, and obvious predator attack marks. Bird marks were identified by symmetrical bruises on each side of the fish.

Fish mortalities were noted by species. All mortalities of natural fish and occasional mortalities of hatchery fish were frozen for later processing by the ODFW La Grande Pathology Lab. Any unusual marks or indications of disease on dead fish were also noted.

Lengths

At each site, all wild fish and a proportion of hatchery fish were measured to fork length to the nearest millimeter. We computed length-frequency distributions, determined modal length frequencies, and estimated mean fork length per species of hatchery and wild fish.

Migrant Abundance and Survival

We estimated migrant abundance for each race or species of salmonid at each sampling site to primarily estimate total outmigration for hatchery and natural fish and, secondarily, to estimate survival for hatchery fish. We estimated overall migrant abundance (A) by expanding the number of unmarked captured fish during the trapping season (C) by the reciprocal of the weighted trap efficiency ($1/TE$) for the collection period ($A = C \times 1/TE$). Recaptured marked fish from collection efficiency tests were subtracted from the total daily collection prior to estimating migrant abundance. We used the bootstrap method (Efron and Tibshirani 1986) with 1,000 iterations to determine variance for each abundance estimate. Confidence intervals (95%) for the abundance estimate were calculated using the square root of the bootstrap variance estimate ($CI = 1.96\sqrt{V}$).

The migrant abundance survival estimate ($S_{ma} = A/R$) was derived from the estimate of migrant abundance (A) and the number of hatchery fish released at the initial release site (R).

We also used the single release-recapture model (Burnham et al. 1987) to estimate survival of marked subyearling fall chinook salmon. Subyearling fall chinook salmon were captured upriver at Furnish Canal (RM 32.5), marked on three successive days with acrylic paint, re-released into the river, and recovered at the West Extension Canal facility. Survival estimation for marked fish (S_m) was derived from the number of marked fish recovered (M) expanded by the reciprocal of the weighted trap efficiency ($1/TE$), divided by the total of marked fish released (Rm), where $S_m = (M/TE)/R_m$). Survival study marks were made with a Panjet air injector, applying a blue, red, or green 1-mm to 2-mm mark on the ventral surface of the body.

Environmental Conditions

Daily operational information on river flow and canal withdrawals were obtained from flow data from the U.S. Bureau of Reclamation's HYDROMET (hydrological-meteorological) data acquisition system. We used canal flow data recorded from stations located at West Extension, Maxwell, Westland, and Feed canals (Figure 1). We used river flow data recorded at stations below Feed Canal and Three Mile Falls dams. In the analysis, we used river flow data collected from the U.S. Geological Survey below Three Mile Falls Dam. We obtained information on water diversion at West Extension Canal from the Oregon Water Resources Department (OWRD, unpublished data). Canal diversion rate was computed using canal flow and adjusted river flow above the canal (adjusted river flow included canal flow).

We obtained river temperature information from the HYDROMET station above Maxwell Dam. At Three Mile Falls Dam, we used mean temperature data collected by CTUIR during adult fish trapping operations (CTUIR and ODFW 1995). We collected daily temperatures at our sampling sites using a Max-Min thermometer.

We recorded observations of various water quality and environmental parameters, including level of river flow, debris load, and turbidity, water color, amount of cloud cover and precipitation, wind intensity, and wind direction. We measured turbidity at West Extension Canal using a standard Secchi disk, measuring the depth (m) at which the disk disappeared from sight as it was lowered and reappeared in sight as it was raised.

Resident Fish and Predators

We noted the presence of avian predators at our sampling sites. Information recorded included species, number, time of observation, where observed, and activity.

Non-salmonid fish were identified by species and counted during the monitoring activities of salmonid species. At Feed and West Extension canals, we counted resident fish on an hourly basis when the trap was staffed 24-hours a day. Otherwise, counts were made once per day.

Fork lengths (mm) were measured on fish species known to be predators of juvenile salmonids, primarily northern squawfish (*Ptychocheilus oregonensis*), smallmouth bass (Micropterus *dolomieui*), and largemouth bass (Micropterus *salmoides*). Lengths were also taken on subsamples of other resident fish.

We determined diel pattern of movement for northern squawfish and suckers (*Catostomus* spp.) at West Extension Canal, based on 100% full-hour sampling.

PIT Tags

Information on PIT tags was collected from various suppliers and users. We attended a PIT tag workshop to gather information on current and future PIT tag use. Within the forum of the Umatilla Monitoring and Evaluation Oversight Committee, we developed a proposal to PIT tag and monitor juvenile salmonids in the Umatilla River basin in 1997.

Statistical Analysis

We used correlation analysis to examine relationships among environmental variables and fish collection data. We used correlation analysis to determine the relationship between total fish collection and river flow or water temperature. We used SAS (Statistical Analysis Systems) for personal computers (SAS Institute 1990) to conduct our analyses.

Confidence intervals for abundance estimates were computed using the bootstrap variance estimate. We used Chi^2 goodness-of-fit tests to determine significant differences among groups of trap efficiency estimates and among brand recovery groups. We used Chi tests of independence to determine differences in injury proportions among weeks. We used t-tests to determine significant differences in fork lengths between hatchery and wild fish. All tests were performed at a significance level of 0.05.

RESULTS

Migrant Traps

Sampling periods and trapping operations are indicated in Table 1. The floating trap net was used at RM 0.5 and the rotary-screw trap was used at RM 1.8. Flooding in February severely damaged the screw trap and it was unusable for further use. We resumed sampling at Feed Canal in late February, using an inclined plane trap in the bypass downwell.

Trap Efficiencies

Estimates of trapping efficiency (TE) for hatchery and wild salmonids at Feed and West Extension canals and the two lower river trapping sites are presented in Tables 2 to 6. Trap efficiencies for hatchery spring chinook salmon subyearlings at RM 0.5 ranged from 0 (no estimate) to 0.259 with a mean efficiency of 0.168 (SD = 0.094; Table 2). All trap efficiency recaptures were collected within one to four hours after release. Trap efficiencies for spring chinook salmon subyearlings at RM 1.8 ranged from 0.125 to 0.385 (Table 2) with a mean efficiency of 0.200 (SD = 0.095). No marked fish were caught after 24-hours from release at this site. In most cases, trap efficiencies calculated from releases of small groups of (n < 28) were similar to larger releases (n > 51).

We used hatchery spring chinook and coho salmon, wild chinook salmon, and wild summer steelhead for trap efficiency estimates at Feed Canal during 8-hour and 24-hour sampling (Tables 3 and 4). Recapture of fish ranged from 1 to 30 days, with most fish recaptured within the sampling period (8 hours) or the first 24-hours after release. During 8-hour sampling from 2 December to 15 March, we marked hatchery spring chinook salmon subyearlings (Table 3). Of four releases made, one had no recaptures. Mean trap efficiency for subyearling spring chinook salmon during 8-hour sampling was 0.261 (SD = 0.427). During 8-hour sampling from 16 March to 19 March, we marked six groups of hatchery spring chinook salmon yearlings; recaptures were obtained from only one of these groups (TE = 0.008; Table 3). Mean trap efficiency for the 25 groups of hatchery coho released during 8-hour sampling was 0.086 (SD = 0.062). Four of these groups (16%) had no recaptures (Table 3). Of trap efficiency releases made for wild salmonids during 8-hour sampling, recaptures were obtained from only two of three groups of wild spring chinook salmon and one of three groups of wild summer steelhead (TE = 0.200; Table 4). Mean trap efficiency for wild spring chinook salmon was 0.434 (SD = 0.067).

During 24-hour sampling at Feed Canal from 20 March to 29 March, hatchery yearling spring chinook salmon were not recaptured from 56% of the trap efficiency release groups (Table 3). Mean trap efficiency was 0.023 (SD = 0.028). Three of the 12 release groups for coho salmon had no recaptures (Table 3). Mean trap efficiency for coho salmon during 24-hour sampling was 0.111 (SD = 0.129). No recaptures were obtained from the seven release groups of wild summer steelhead during 24-hour sampling (Table 4).

At West Extension Canal, seven trap efficiency releases were made for hatchery yearling spring chinook salmon from 31 March to 7 April (Table 5). Of these, three groups (43%) had no recaptures. Recapture of fish from mark groups ranged from 1 to 22 days. Earliest recaptures were 10 hours after the 1900-hour release. Mean trap efficiency for yearling spring chinook salmon was 0.136 (SD = 0.174).

After 7 April, 36 trap efficiency releases were made for combined yearling fall and spring chinook salmon from 8 April to 17 May (Table 5). Of these, eight groups (22%) had no recaptures. Recapture of fish from mark groups ranged from within 1 to 34 days. fish were recaptured 3 hours after the morning release. Most marked fish were recaptured from 1300 - 2000 hours and 0600 - 0800 hours. Mean trap efficiency for yearling fall and spring chinook salmon was 0.102 (SD = 0.112).

Forty-two trap efficiency releases were made for hatchery coho salmon from 31 March to 17 May, and one release on 5 July (Table 5). Of these, 22 groups (51%) had no recaptures. Recapture of fish from mark groups ranged from within 1 to 32 days, with most fish recaptured within the first week after release. Fish were generally recaptured between 1300 - 1800 hours and 0700 - 0900 hours; the earliest recapture was 1 hour after release. Mean trap efficiency for yearling coho salmon was 0.040 (SD = 0.102).

Sixteen trap efficiency releases were made for hatchery summer steelhead from 14 April to 2 June (Table 5). Of these, seven groups (44%) had no recaptures. Recapture of fish from mark groups ranged from 1 to 26 days, with most fish recaptured within the first two days after release (Table 5). Fish were generally recaptured from 1300 - 2400 hours; the earliest recapture was 2 hours after release. Mean trap efficiency for hatchery summer steelhead was 0.056 (SD = 0.063).

Two separate trap efficiency groups were apparent for fall chinook salmon subyearlings (Table 5). Chi^2 testing indicated that the overall trap efficiency prior to 1 June and on and after 1 June were significantly different (X^2 = 702.6, $P < 0.001$). From 23 May to 31 May, trap efficiency tests were conducted with subyearling fish that escaped from the upriver acclimation ponds. Eight efficiency releases were made during this time and a minimum of 22 fish were recaptured from all groups. The mean trap efficiency estimate was 0.506 (SD = 0.116). Recapture of fish from these mark groups ranged from 1 to 20 days after release with most fish recaptured within 24 hours and as early as 2 hours after release (Table 5). Beginning 1 June, operations at West Extension Canal changed and trap efficiencies dropped to a mean of 0.079 (SD = 0.083) from 13 releases made. These trap efficiency tests were conducted with subyearling fish that were released on 31 May and continued until 16 June. Four of these releases (31%) had no recaptures.

Overall mean trap efficiency for releases of subyearling fall chinook salmon from 23 May to 16 June was 0.240 (SD = 0.229). Fish from these release groups were recaptured from 1 to 7 days after release. Most fish were recaptured within 10 hours after release and as early as 2 hours after release. Fish were predominantly recaptured from 1200 - 1400 hours; recapture usually continued until midnight and then resumed near 0600 hours.

Same day trap efficiencies for different hatchery species were generally not similar. Overall, coho salmon and summer steelhead were not recaptured as readily as yearling and subyearling chinook salmon.

Few wild fish were recaptured during trap efficiency tests at West Extension Canal (Table 6). Wild summer steelhead and spring chinook salmon were recaptured almost solely within the first day after release. We recaptured no wild coho or wild subyearling fall chinook salmon during trap efficiency releases. Of the 12 groups of wild summer steelhead released from 3 April to 30 April, six (50%) groups had no recaptures. Mean trap efficiency for wild summer steelhead was 0.085 (SD = 0.117), greater than that for hatchery summer steelhead. Of the five groups of wild spring chinook salmon released from 6 April to 15 April, three groups (60%) had no recaptures. Mean trap efficiency was 0.026 (SD = 0.033), less than the efficiencies for hatchery chinook salmon.

Outmigration Monitoring

Collection

We monitored the outmigration of juvenile salmonids from mid-November 1994 through September 1995. We did not sample most of February due to flooding and trap damage nor most of August due to equipment repair and maintenance at West Extension Canal. Monitoring was continuous throughout the day only at the rotary screw trap in late January, at Feed Canal in late March, and at West Extension Canal from early April to mid-June (Table 1).

We collected 1,481 juvenile salmonids at the RM 0.5 site, mostly hatchery subyearling spring chinook salmon (Table 7). Sampling was initiated 2 days after subyearling spring chinook salmon were released in fall of 1994. We sampled during the day up to 8 days post-release; thereafter, we sampled at night (Table 1). Total collection of hatchery subyearling spring chinook salmon represented 0.4% of the release.

Few fish (183) were captured during sampling at the rotary-screw trap (RM 1.8) in mid- to late January (Table 7). Most (81%) were hatchery subyearling spring chinook salmon; wild subyearling spring chinook salmon and wild summer steelhead were also captured.

A total of 10,037 juvenile salmonids were captured at Feed Canal from early December 1994 to late March 1995 (Table 7). Collected numbers during 8-hour sampling were not expanded; collections made during 24-hour sampling were adjusted for subsampled hours. Hatchery yearling spring chinook salmon comprised 66% of the total; hatchery coho comprised 28%. Number of hatchery subyearling spring chinook salmon captured dwindled to 186. Wild summer steelhead and wild subyearling coho and spring chinook salmon comprised about 4% of the total collection.

Most hatchery and wild juvenile salmonids were monitored at West Extension Canal from late March through September, with nearly three-quarter million fish passing through the bypass facility (Table 7). Data collected was expanded for hours bypassed and hours subsampled, representing 1.7% and 9.6% of the total sample hours, respectively. Coho salmon comprised 56% of the hatchery fish collected, yearling spring and fall chinook salmon comprised 30%, subyearling fall chinook salmon comprised 11%, and summer steelhead comprised 2.4%. Spring chinook salmon and summer steelhead comprised 32% and 62% of the wild species collected. Wild subyearling fall chinook and coho salmon were present in the collections in relatively small numbers (Table 7).

Daily sampling at Maxwell Canal in late June revealed an increasing abundance of wild subyearling fall chinook salmon by month's end, comprising 31% of the total collection (Table 7). These fish were smaller than their hatchery counterparts.

The juvenile fish holding pond at Westland Canal was sampled on five different dates within two weeks in June (Table 8). Most fish collected from 13 June to 22 June were hatchery subyearling fall chinook salmon, although wild fall chinook subyearlings were increasing in proportion. By 27 June, wild fish dominated the samples (68.8%). Few other salmonid species were collected.

Fish densities changed in relation to sampling location within the juvenile holding pond at Westland Canal (Table 8). Percent composition of hatchery and wild fall chinook salmon subyearlings was fairly uniform among all sampling locations, except for 27 June. On this date, proportions were different between the middle, left, and right areas of the pond. Non-salmonid abundances were too low to evaluate distribution uniformity.

We collected 468 samples of scales for age analysis by CTUIR biologists (Table 9). Most scales were from wild summer steelhead. Scales were collected from early December 1994 to July 1995.

Brands

Brand release groups were collected in similar proportions to each other, with only a few exceptions (Table 10). The percentage of summer steelhead collected from steelhead released on 12 May (RAB4 brand) was 0.7% and 1.3% less than the other two brands released in mid-April; the RAB1 brand released on 11 April was predominant (2.3%). Chi^2 goodness-of-fit test indicated all brand proportions were significantly different from each other ($P < 0.001$). Expanded by weighted trap efficiency, the RAB1 brand had nearly a 10% greater survival index than the other two brands. The mean survival index from all three brands was 20.5% (SD = 6.8).

Brands on yearling spring chinook salmon from Umatilla Hatchery and released in mid-March were first detected at Feed Canal in mid-March and later detected during sampling at West Extension Canal in April (Table 10). Recapture of these branded fish accounted for 0.2% to 0.7% of the branded fish released. Two groups of yearling spring chinook salmon from the Bonneville Hatchery were also branded (RAB3 and RAB2) and released in mid- and late April. These branded fish were recaptured more than the other brand groups from Umatilla Hatchery, representing between 6% and 8.2% of the branded fish released. Excluding the Bonneville brands, remaining brand proportions were significantly different from each other (X^2 = 22.4, $P < 0.001$). Significance was primarily attributed to the RAB4 brand, and secondarily to the LAB4 brand. Expanded by appropriate weighted trap efficiencies, brand survival indices ranged from 4% to near 31% for early-released groups (mean = 19.1; SD = 9.2), and greater than 70% for later-released groups (mean = 79.5; SD = 7.9). The overall mean survival index was 34.2% (SD = 27.6).

Except for the RAL1 and RAE2 brands on the subyearling fall chinook salmon, all brands collected represented 1.4% to 2.2% of the brands released (Table 10). The exceptions were from two groups of fish escaping from upriver acclimation ponds. Excluding the RAL1 brand, all brands representing rearing in Michigan ponds at Umatilla Hatchery (1, 3, and 4 positions) were not significantly different from each other (X^2 = 5.4, P = 0.250). Excluding the RAE2 brand from Oregon-reared brand groups (all 2 positions), brand group recovery was significantly different (X^2 = 14.9, P = 0.001) due to low recovery of the LAL2 brand. Expanded by appropriate weighted trap efficiencies, survival indices represented by all brands ranged from 11.7% to 18.2%, with a mean survival index of 14.0% (SD = 2.5). Mean survival index of Michigan-reared fish (all brands in the 1, 3, or 4 position) was 12.6% (SD = 1.0). Mean survival index of Oregon-reared fish (all brands in the 2 position) was 16.1% (SD = 2.6).

Fin Clips

Fin clips on salmonids were observed in similar proportion to the number released for summer steelhead (AD - 2.6%, ADLV - 2.7%) and fall-released subyearling spring chinook salmon (RV and ADRV - 0.5%; Table 11). Fin clips on yearling spring chinook and subyearling fall chinook salmon (ADRV/RV) were observed disproportionately (Table 11). Fish with the ADRV clip on both species were observed 50% less than the RV clip. The inability to differentiate yearling spring chinook from yearling fall chinook salmon after 7 April may have contributed to the disparity between the proportion of RV and ADRV clips. The inability to adequately or accurately note fin clips on subyearling fall chinook salmon during the short, intense collection period at West Extension Canal may have contributed to the extremely low observations of the ADRV clip.

Migration

Hatchery subyearling spring chinook salmon released on 13 November 1994 were first recaptured during the day on 18 November at RM 0.5. On November 28, migration numbers peaked (425) and progressively declined to 10 fish during 8-hour sampling on 13 December. Expanded by trap efficiency, an estimated 3,542 fish passed the trap on 28 November (0.120). Based on recapture time of trap efficiency releases, weighted average travel time from release point to the trap (0.7 miles) was 1.8 hours.

At Feed Canal, most hatchery subyearling spring chinook salmon were caught in December, but continued to be captured until late February (Figure 7). Initial releases of hatchery coho salmon in the Umatilla River (RM 42.5) were made daily between 21 February - 1 March. Our first recapture from these releases was on 22 February (Figure 7). These fish migrated an estimated 13.3 miles/day. Coho salmon recapture peaked during 8-hour sampling on 24 February (527 fish), followed by a second peak on 4 March (311 fish), and a final peak on 16 March (114 fish). After this, coho recaptures were less than 50 fish per day, even after 24-hour sampling.

Hatchery yearling spring chinook salmon released on 13 March at RM 80 were captured the same day at Feed Canal in peak numbers (5,204 fish; Figure 7). Front runners migrated 50.8 miles in less than a day. There were two secondary peaks on 16 March (329 fish; 8-hour sampling) and 25 March (160 fish; 24-hour sampling). After this, fish numbers declined to 21 fish by end of March.

Collection of wild juvenile salmonids at Feed Canal was initially dominated by subyearling spring chinook salmon in December and later by summer steelhead in mid-March (Figure 7). In general, wild fish numbers remained near or below 10 fish/day from early December to late March.

At West Extension Canal, hatchery coho salmon numbers peaked on 8 April (16,941 fish), following the second and third releases made daily from 29 March - 31 March and 31 March - 4 April (Figure 8). Following the last release of coho salmon made on 6 April and 7 April, peak collection was on 29 April (80,406 fish) and 2 May (124,852 fish). Date of 50% cumulative capture was 2 May, Collection of > 10 coho salmon per day continued to 1 June, afterwhich coho salmon were incidentally captured into mid-July.

Hatchery yearling summer steelhead peaked the second day after steelhead were first caught at West Extension Canal (1,554 fish; 13 April) and two days after the first release (11 April; Figure 8). These fish migrated 39 miles/day from Bonifer (RM 2 on Meacham Creek at RM 79) to RM 3 on the Umatilla River. The second peak was on 15 April (693 fish), two days after the second release on 13 April. The largest hatchery summer steelhead peak (2,412 fish; Figure 8) was on 28 April. Median (50%) cumulative capture was reached on 29 April following the first two releases. Steelhead recaptures sharply declined in early May. The final peak in hatchery summer steelhead was on 22 May (618 fish), ten days after the last release (12 May). Summer steelhead were collected into early June.

Hatchery yearling spring / fall chinook salmon reached 50% cumulative capture on 25 April (Figure 9), following a release of fall chinook salmon on 7 April and subsequent spring chinook salmon releases on 14 April and 21 April at KM 73.5. The two races could not be differentiated due to the same fin clip. Peak collection was 26 April (29,495 fish), followed by a secondary peak on 28 April (22,058 fish; Figure 9). Collection of > 10 yearling chinook salmon per day at West Extension Canal continued to 23 May, with incidental captures into early June.

Estimates of cumulative capture of subyearling fall chinook salmon were confounded by the early escape of fish from upriver acclimation ponds. Escapees were first captured on 16 May (Figure 9); the official release was on

31 May. Approximately 41,500 escapee fish were collected by 31 May, comprising half of all subyearling fall chinook salmon passing through the West Extension Canal facility (Figure 9). The released subyearlings traveled from release sites at RM 73.5 and RM 80 to the RM 3 capture site in two days, traveling 37.3 miles/day. Using hydroacoustics, we detected large schools of fish congregating at the canal trashracks on 2 June at 1630 hours. On 3 June, approximately 70 hours after release, capture peaked (30,264 fish; Figure 9). Trap counts sharply increased from < 100 fall chinook salmon per hour to > 1,000 fish per hour at 0800 hours on 3 June. Counts remained high for the next six hours, peaking at 1200 hours (6,380 fish). Counts subsided to < 100 fish per hour by 2000 hours. During this period (0800 - 2000 hours), approximately 23,900 fall chinook subyearlings passed through the bypass facility. Trapping and hauling operations for all migrants were initiated on 8 June at Westland Canal (RM 27.3). By 11 June, less than 50 subyearlings were being captured at West Extension Canal over 24-hour sampling. Collection of > 10 subyearlings per day continued to 19 June when the facility was temporarily shut down. Last capture was on 8 July.

The first peak in wild summer steelhead captured at West Extension Canal was 8 April (296 fish), three days before the first release of hatchery summer steelhead and five days before the hatchery fish peak (Figure 10). A second substantial peak of wild steelhead followed on 28 April (443 fish), the same day as the final peak for hatchery steelhead. Fifty percent cumulative capture of wild summer steelhead occurred on 29 April, one day after the second peak (Figure 10). The final peak in wild steelhead numbers was on 19 May (95 fish) afterwhich the number captured steadily declined. Last capture was on 10 June (1 fish).

The most active migration period for wild chinook salmon was the first three weeks of April. Wild chinook salmon (springs) were first captured in large numbers on 8 April (198 fish), followed by a second, major peak on 16 April (882 fish; Figure 10). The last wild spring chinook were captured in mid-May. Also in mid-May, subyearling wild fall chinook salmon appeared in collection samples. The largest peak for subyearling fish was on 2 July (11 fish). Fifty percent cumulative capture of wild chinook salmon was on 16 April (Figure 10) and was based on collections of yearling and subyearling chinook at West Extension Canal.

Wild coho salmon were collected in samples from early April through the end of April and again from mid-May to early August. Peak numbers were collected on 29 April (37 fish).

Diel Movement

At RM 0.5 in fall 1994, very few subyearling spring chinook salmon were caught during daytime sampling; more fish were collected later in the day (1600 - 2200 hours). Fish numbers started to increase around sunset and peak hour of collection was 1900 hours (544 fish; Figure 11).

Hatchery coho and spring chinook salmon at Feed Canal in late March had similar diel movement (Figure 12). Coho salmon movement peaked around early morning (0600-1000 hours) and night (1900-2400 hours). Usually fewest fish were caught between 1200 and 1800 hours. Most yearling spring chinook salmon moved at night between 1900 and 2100 hours. Fewest fish were caught between 0900 and 1800 hours. These peak movements coincided with the times of sunrise and sunset for the month of March. Wild summer steelhead movement peaked after sunrise and sunset; movement was lowest during midday.

At West Extension Canal in April, hatchery coho salmon showed an unusual peak in movement at 0300 hours (> 60,000 fish; Figure 13). (This value may have been due to expansion of the data during non-sampled hours). Capture throughout other hours ranged from 2,300 fish to 8,900 fish (0700 hours). In May, hatchery coho salmon movement was greatest between 0600 - 0800 hours, immediately after sunrise.

Hatchery yearling chinook salmon had two peak diel movements in April at West Extension Canal, from 0600 to 0700 hours and from 1300 to 1800 hours (Figure 14). These movement patterns were at and after sunrise and prior to sunset. In May, hatchery chinook salmon were captured in largest numbers during midday at 1100 hours and 1400 hours. In April, wild yearling chinook salmon moved more at 1700 hours, immediately prior to sunset (Figure 14).

Subyearling fall chinook salmon peaked in diel movement at three different periods in May (Figure 15; 0600 - 0700 hours, 1300 hours, and 1600 - 1800 hours). In June, most fish were collected between 1100 and 1200 hours. June diel movement was mostly represented by the two days when the main contingent of subyearling chinook salmon passed through the sampling facility (3 June and 4 June).

Similar to coho salmon, hatchery summer steelhead collections peaked at 0300 hours in April (> 1,000 fish/hour; Figure 16). A second peak occurred a 1500 hours, four hours before sunset. In May, most summer steelhead moved into the sampling facility at 1600 hours, four hours before sunset. In June, peak collections shifted to 0800 - 0900 hours, 1200 - 1300 hours, and 1900 hours.

Wild summer steelhead showed a distinct diel pattern in April, but not in May (Figure 17). In April, movement peaked at 2000 hours, with secondary peaks at 0600 and 0700 hours. These peaks coincided with the onset of sunrise and sunset.

Smol t Index

Index of smoltification changed to smolt status over time for both hatchery and wild fish (Figure 18). The transition from parr to smolt was most pronounced for hatchery coho salmon. Most fish were classified as parr at release (February, March), then smolted by late April. The predominance of coho smolts corresponded to their peak collection at West Extension Canal in late April and early May (Figure 8). In contrast, wild coho were classified as parr during most of their outmigration from mid-February to early June (observations of wild coho classified as intermediate and smolt occurred more in late April).

Hatchery yearling spring chinook salmon collected at Feed Canal soon after release in March were 50% or greater smolted (Figure 18). Later yearling spring chinook migrants (prior to the 7 April release of yearling fall chinook salmon) were not as smolted as earlier arrivals, with 75% classified as intermediate. After the April releases of fall and spring chinook salmon, most or all of the fish collected were smolts. Wild spring chinook salmon showed a mix of predominantly intermediate or parr up until mid-April when greater than 60% of the fish were considered smolts.

Hatchery summer steelhead were not all smolted at first capture in early April (Figure 18). By late April, all steelhead collected were considered smolts. Wild summer steelhead showed a gradual transition toward smolt status from late March to early June. Subyearling fall chinook salmon released in late May were nearly 100% smolted at capture.

Fish Condition

Condition of hatchery fish declined due to bird predation, bacterial kidney disease, varying degrees of scale loss, and other injuries including injury to the head, eyes, operculum, and body. Secondary fungal infections, parasites, and leeches were also present on hatchery fish (Appendix Table A-1). Over time, fish condition deteriorated, more so with hatchery fish than wild fish.

At Feed Canal, condition was not significantly different between weeks for hatchery or wild coho salmon, wild summer steelhead, or wild chinook. However, condition was significantly different for hatchery yearling spring chinook salmon between the last two weeks in March ($X^2 = 27.88$, $P < 0.001$) primarily due to increased percentages of bird marks and injury. More than 85% percent of the subyearling spring chinook salmon released in fall 1994 and recaptured at in-river traps and Feed Canal had minimal scale loss. However, bird marks and descaling (< 8%) increased proportionately with time.

Hatchery summer steelhead experienced the most drastic decline in condition, as shown in long-term sampling at West Extension Canal (Appendix Table A-1). Bird marks were frequently observed on steelhead, ranging from 1% to 14.5% of the fish sampled by week. Scale loss on summer steelhead was also higher than any other hatchery species. Greater than 10% of the fish collected after late April were descaled; earlier sampled fish exhibited minimal descaling (1.4% - 2.9%). Chi^2 tests indicated that condition was not independent of time (weeks), primarily due to proportional changes in scale loss and bird marks (Appendix Table A-1).

Signs of bacterial kidney disease increased with time on hatchery yearling spring and fall chinook salmon; disease symptoms were noted on 25% of the fish collected by late May as mortality rose to near 3% (Appendix Table A-1). Leeches were present on about 1% of the fish during their early migration. Scale loss, bird marks, and injury showed no trends, but were highest toward the end of May. Chi^2 tests indicated that condition was not independent of time (weeks), primarily due to proportional changes in scale loss, bird predation, signs of bacterial kidney disease, and injury (Appendix Table A-1).

Hatchery subyearling fall chinook salmon succumbed to deteriorating water conditions from mid- to late June. In mid-June at West Extension and Westland canals, nearly 10% of the fall chinook salmon sampled were dead or moribund (Appendix Table A-l). Mortality decreased the last week in June (0% -2.2%). Pathological analysis indicated that these fish were infected with moderate levels of *Ichthyophthirius*, moderate to high levels of bacterial gill disease, and a low level of Aeromonad-pseudomonad bacteria in the kidneys (ODFW, unpublished data). Scale loss on these fish was near 1% in late May, but > 40% by July at West Extension Canal. Chi^2 tests indicated that condition was not independent of time (weeks) at West Extension and Westland canals, primarily due to proportional changes in mortality, and secondarily to changes in scale loss and bird marks at West Extension Canal (Appendix Table A-l). About 1% of the fish sampled at this site during the first week after their release in early June had bird marks.

Hatchery coho salmon were in best condition throughout the migration compared to other hatchery species of fish. At West Extension Canal, greater than 85% of the fish were in good condition from late March to mid-June; scale loss slightly increased to about 7% in July (Appendix Table A-l). Bird marks and other injuries were also relatively low (2.1% and 7.4%, respectively). Overall, less than 0.8% of coho salmon were dead or moribund and none showed signs of bacterial kidney disease. Chi^2 tests indicated that condition was not independent of time (weeks), primarily due to proportional changes in scale loss, injury, and bird predation (Appendix Table A-l).

Condition of wild juvenile salmonids was consistently better than their hatchery counterparts in regard to scale loss and other injuries. Most wild summer steelhead (67%) and wild coho salmon (87%) sampled at Feed Canal and wild coho salmon (82%) sampled at West Extension Canal had a 90% or greater level of minimal scale loss (good condition) during weekly sampling (Appendix Table A-l). Only about 1% of all wild summer steelhead sampled at West Extension Canal were descaled and only 4.3% were partially descaled. Injuries (without scale loss) were minimal to wild summer steelhead (1.2%), wild yearling chinook (2.8%), and subyearling coho salmon (1.2%); injuries were non-existent on wild subyearling fall chinook salmon at West Extension Canal. Pathological analysis on two wild steelhead and one wild spring chinook salmon indicated low levels of Rs antigen (BKD) with no presence of the disease, and no detection of systemic bacteria (ODFW, unpublished data).

All species of wild salmonids were infested with the parasite *Neascus metacecaria* (Black spot disease). The disease was apparent by the encrusted black spots under the skin which were the imbedded metacercaria of the parasite's life stage. Highest incidence of black spot disease was found on wild chinook salmon collected at Feed Canal in early December (40.6%). Signs of this disease continued to be found on wild chinook salmon from early April to mid-May at West Extension Canal. Wild summer steelhead, coho salmon, and subyearling fall chinook salmon exhibited black spot disease less than wild chinook salmon (Appendix Table A-l).

Wild summer steelhead collected at West Extension Canal had more bird marks than any other wild species. Prevelance of bird marks increased from 3.6% in mid-May to 20% by mid-June.

Death rates of wild subyearling fall chinook salmon were less than their hatchery counterparts at Westland Canal in mid-June (7.6%) and similar at Maxwell Canal in late June (1.8%). Five of the 22 wild subyearlings caught at Westland Canal in early July were dead.

Lengths

Length-frequency distributions were different between wild and hatchery spring chinook salmon at Feed Canal in March 1995 (Figure 19). Length mode for wild chinook salmon was 100 mm; mean fork length was 100.8 mm (Table 7). Bimodal length frequencies for hatchery spring chinook were 165-174 mm and 130 mm, representing the yearling and subyearling populations, respectively. Respective mean fork lengths were 167.8 mm and 129.8 mm (Table 7). Wild coho salmon collected at Feed Canal were all less than 100 mm in fork length with a mean length of 87.8 mm (Figure 19; Table 7). Modal length frequency for hatchery coho salmon was 130 mm; mean fork length was 126.7 mm (Table 7). Modal length frequency for wild summer steelhead was 145 mm. Mean fork length was 141.9 mm (Table 7), ranging from 75 mm to 250 mm.

At West Extension Canal, modal length frequency for all yearling chinook salmon ranged from 175 mm to 184 mm (Figure 20); mean fork length was 168.5 mm (Table 7). A distinct length-frequency mode of 145 mm was evident for hatchery coho salmon; mean fork length was 142.7 mm (Table 7). Mean length of hatchery coho salmon increased 20 mm from March to August. Modal length frequency of hatchery summer steelhead was 220 mm, representing the three different size groups reared and released (smalls, mediums, and larges; Hayes et al. 1996). Mean fork length for hatchery steelhead (sizes combined) was 214.5 mm (Table 7). Too few lengths were measured on hatchery subyearling fall chinook salmon to derive a distribution, but mean fork length was 88.7 mm (Table 7).

Mean fork lengths of wild salmonids were significantly smaller than hatchery fish of the same species ($P < 0.001$). Lengths for wild chinook salmon ranged from 38 mm to 201 mm between April and July 1995, representing the fall and spring races of migrants (Figure 21). Larger fish (spring chinook) were dominant in April and May (modal length = 105 mm; mean fork length = 113.1 mm); smaller fish (fall chinook) were dominant in June and July (modal length = 55 mm; mean fork length = 68.1 mm). Modal length frequency for wild coho salmon was between 36 mm and 50 mm (Figure 21) with a mean fork length of 66.3 mm (Table 7). Alevins (20 mm), presumed to be wild coho salmon, were also collected. Wild coho salmon could only be differentiated from hatchery coho based on length; coho salmon less than 100 mm were considered wild (personal communication, G. Rowan, CTUIR, Pendleton, OR). Length-frequency mode for wild summer steelhead was 185 mm; fork lengths ranged from 95 mm to 335 mm (Figure 21). Mean fork length was 179.0 mm (Table 7). Mean length of wild steelhead increased approximately 40 mm from March to August 1995.

Migrant Abundance and Survival

Abundance estimates were determined for most salmonids collected at West Extension and Feed canals and at lower river trapping sites where trap efficiency estimates were obtained (Table 12). Abundance of hatchery spring chinook salmon subyearlings was greatest during sampling at RM 0.5 from November to December 1994 (8,133 fish). This is not a total abundance estimate as we sampled only for 8 hours out of the day for 11 days. Our abundance estimates steadily declined during 24-hour sampling at RM 1.8 and 8-hour sampling at Feed Canal. Again, estimates were based on intermittent sampling. Weighted trap efficiencies at each of the three sites were similar to each other (Table 12). In total, 9,657 subyearling spring chinook salmon passed the three sampling sites. This estimate represents 2.6% of the spring chinook salmon released in November. Ninety-five percent confidence limits on the three estimates combined provided an upper bound of 11,983 fish (3.2% minimum survival) and a lower bound of 7,331 fish (1.9% minimum survival).

Wild spring chinook salmon collected at RM 0.5 (9 fish; Table 7) and passing RM 1.8 (216 fish) and Feed Canal (430 fish) comprised an abundance estimate of 655 fish. The abundance estimate for wild spring chinook salmon passing Three Mile Falls Dam (73,696 fish) was based on intensive, continuous sampling and a weighted trap efficiency of 0.023 (Table 12). The 95% confidence interval was wide, providing an upper bound of 191,687 fish and a lower bound of 0 fish.

The estimate of hatchery yearling spring chinook at Feed Canal (289,217 fish; Table 12) represents 65.5% of the number released on 13 March (Table 7). Upper and lower 95% confidence limits (157,672 and 420,762 fish) represent respective survival estimates of 35.7% and 95.4%. These fish continued to be captured at West Extension Canal, but could not be differentiated from fall chinook yearlings after 7 April. Prior to 7 April at West Extension Canal, 266 spring chinook yearlings were captured (Table 7) and expanded to an abundance estimate of 4,836 fish (Table 12). Overall, we estimated that at least 294,053 spring chinook yearlings released in mid-March passed through the lower river (66.6% survival).

An estimated 29,798 hatchery coho salmon passed Feed Canal Dam from late February to late March (Table 12). This estimate represents 9.2% of the coho salmon released during this period (Table 7). Upper and lower 95% confidence limits (34,315 and 25,281 fish) represent respective survival estimates of 7.8% and 10.6%. At West Extension Canal, coho salmon abundance (33,967,417 fish) far exceeded the total number of coho salmon released (1,514,266 fish), based on a weighted trap efficiency of 0.012. Confidence intervals were not computed due to the large overestimation and extensive computer time required.

Hatchery yearling chinook at West Extension Canal (comprised of spring and fall chinook salmon) were also overestimated. With a total April release of 549,880 yearling spring and fall chinook salmon (Table 7), the abundance estimate for yearling chinook salmon collected after 7 April (2,341,223 fish) was over 4 times the release number (Table 12).

The abundance estimate for hatchery summer steelhead at West Extension Canal (225,139 fish; Table 12) also exceeded the number of steelhead released (146,463 fish; Table 7) by 1.5 times. The lower confidence limit of this estimate (182,425 fish) was above the number released as well (Table 12). Wild summer steelhead abundance was estimated at 54,361 fish, with an upper bound of 87,171 fish and a lower bound of 21,551 fish.

Total abundance estimate of hatchery fall chinook salmon subyearlings was 420,608 fish (Table 12). Although 2,466,298 fish were released at RM 73.8 and RM 80 (Table 7), approximately 1,529 pounds of juvenile salmonids were collected at Westland Canal and transported to the mouth of the Umatilla River (CTUIR and ODFW 1995). Based on a weighted average of 63.1 fish/lb (CTUIR, unpublished data), about 96,480 fall chinook subyearlings were transported.

Given that 2,369,818 fish remained in the river, our estimate of survival was 17.7%. Upper and lower 95% confidence limits for abundance were 451,196 and 390,020 fish, representing upper and lower survival estimates of 19% and 16.5%. Including transported fish, overall survival was 21%. .

We did not determine abundance estimates for wild subyearling fall chinook and coho salmon because their size and low numbers precluded trap efficiency estimates. There was no upriver marking of wild salmonid species for survival estimation in 1995.

Our estimate of survival for subyearling fall chinook salmon, based on release-recapture of marked fish at RM 32.5, varied from 8% to 62% with a mean of 40.8% (SD = 23.3; Table 13). The two later releases were recaptured in greater and similar proportions to each other than the first release. Survival tests were not conducted on other hatchery species due to low capture of fish for marking or limited personnel.

Environmental Conditions

Umatilla River flow was extremely variable during the 95 water year (1 October 1994 - 30 September 1995; Figure 22). There were numerous high flow events from mid-December to mid-May, with the most severe flooding in early February (6,530 cfs below Three Mile Falls Dam). Flow patterns at Feed Canal Dam mirrored those at Three Mile Falls Dam, although flow was not as great. (From December through March, irrigation withdrawals at Feed Canal Dam reduced total river flow at the downriver gauging station). High flow was due to snowmelt or rain in the upper watershed, which at times forced water releases from McKay reservoir. Mean flows during April, May, and June at Three Mile Falls Dam were 877 cfs, 2,398 cfs, and 205 cfs, respectively. In July and August, flow was usually less than 100 cfs in the lower river.

Daily river temperature measured near Maxwell Dam (RM 14.8) from 1 October 1994 to 30 September 1995 showed a minimum of 33°F (0.6"C) on 3 January and a maximum of 76°F (24°C) on 19 July (Figure 23). Difference between mean and maximum water temperature was generally 1" - 2°F from 1 October 1994 to late March 1995 and during September 1995. From late March to late August 1995, this difference increased to 2" - 5°F. At Three Mile Falls Dam, average mean water temperature in March, April, May, and June was 51.3"F (10.7"C), 57.6"F (14.2"C), 62.9"F (17.2"(Z), and 71.5"F (21.9"(Z) (CTUIR and ODFW 1995).

Daily fish collection at the West Extension Canal was related to flow. In general, more fish were collected on the ascending limb of increasing river flow and lasted for only a few days (Figure 24). Highest collection for all species combined occurred in late April and early May as river flow began to dramatically increase from < 1,000 cfs to > 5,000 cfs. Although the linear correlation between fish number and river flow was not strong (r = 0.24), it was significant f = 0.03).

Daily fish collection at West Extension Canal also was related to water temperature at RM 14.8. Generally, more fish were collected on the descending limb of temperature peaks (Figure 25). Although the negative linear correlation between fish number and water temperature was weak (r = -0.22), it was significant (P = 0.04). Highest collection for all species combined occurred in late April as water temperature dropped nearly 10°F (4.6°C) (Figure 25). Water temperatures were inversely related to river flow (Figures 24 and 25). Fish passage was pressed between the rise and fall of these two variables.

Resident Fish and Predators

Dominant resident fish species at all sampling sites were bridgelip and largescale suckers (Catostomus *columbianus* and C. *macrochelius*), redside shiners (*Richardsonius balteatus*), and northern squawfish (*Ptychocheilus oregonensis;* Table 14). Chiselmouth (*Acrocheilus alutaceus*) was a major non-salmonid species at all sites except Maxwell Canal. Speckled dace *(Rhinichthys osculus)* were common only at Feed Canal, and bass species (Micropterus spp.) were common only at West Extension Canal. These species accounted for 84% to 96% of all non-salmonid fish captured (Figure 26). Adult and juvenile Pacific lamprey *(Entosphenus tridentatus)* were also captured in the floating net trap and screw trap (6 juveniles) in December and January and at West Extension Canal (adults and juveniles), in April (9), May (24), and June (2).

Northern squawfish and bass spp. were the only confirmed salmonid predators captured (Table 14). Squawfish were captured at all sites and contributed most to the total non-salmonid catch at Westland Canal in June (13.3%; Figure 26).

At West Extension Canal from April to September, sucker (Catostomus) spp. accounted for 14% to 64% of the total non-salmonid captures (Figure 27). Squawfish comprised 1% (September) to 21% (August) of total non-salmonid species captured during the same period.

Diurnal patterns were observed for northern squawfish and sucker spp. at West Extension Canal during 24-hour sampling (Figure 28). In April, more suckers were collected at 2200 and 2300 hours; more squawfish were collected at 2200 hours. In May, sucker collections peaked at 0300 hours and 2100 hours and squawfish numbers peaked at late night (2300 and 2400 hours). In June, more suckers were collected at 1900 and 2000 hours; more squawfish were collected at 1500 hours.

Squawfish length-frequency distribution from Feed Canal shows a length mode at 50 mm (Figure 29). Length-frequency distributions of squawfish from West Extension Canal for April-May and June-September show length modes of 130 mm and 250 mm, respectively. These two separate modes represent the younger-aged squawfish prevalent in the spring and the older-aged squawfish dominant from summer through fall. Large squawfish were captured more after 1 June because separation by size was eliminated at the trap's separator box.

Bass (largemouth and smallmouth) were captured at all sites except Westland Canal (Table 14). More bass were captured at West Extension Canal (20.6%, Figure 26), especially during July and August (25.7% and 38%, Figure 27). Nearly all bass collected were young-of-the-year. Length-frequency distribution of bass from West Extension Canal includes smallmouth (Micropterus *dolomieu)* largemouth (*M. salmoides*), and unidentified bass

(Figure 30). Length mode for bass species was 50 mm. Mean fork lengths of bass from West Extension Canal were 113 mm for smallmouth, 89 mm for largemouth, and 55 mm for unidentified bass (Table 14).

The most commonly observed bird predator on fish at Feed and West Extension canals was gulls (*Larus* spp.;Table 15). At Feed and West Extension canals, gulls represented over 70% of the birds observed and were most active in feeding when more juvenile fish were actively migrating. Great blue herons (*Ardea herodias)* and other heron species were the second most common predator. They were most active at night or early morning, primarily at the bypass facilities. At West Extension Canal, more species of bird predators were observed, including double-crested cormorants (*Phalacrocorax auritus*; Table 15).

PIT Tags

We developed a proposal to use Passive Integrated Transponder (PIT) tags after consultation with manufacturers and users and with the Umatilla Monitoring and Evaluation Oversight Committee. The proposal stipulated that ODFW and CTUIR would work cooperatively to implement a pilot study on the use of PIT tags in the Umatilla River. Primary detection sites would be at the West Extension Canal bypass facility and at the rotary-screw trap. We planned to tag yearling summer steelhead and subyearling fall chinook salmon from Umatilla Hatchery and wild spring chinook salmon and summer steelhead from the upper Umatilla River and its tributaries. We would monitor their outmigration throughout the spring and summer. Since the planned advent of 134.2 kHz tags and detectors at John Day Dam was scheduled for 1998, we recognized the need to defer test use of PIT tags until 1997.

DISCUSSION

Trap Efficiency

River flow and diversion rate at West Extension Canal appeared to be the primary factors affecting recapture of trap efficiency fish during late April and early May. When river flow was less than 1,500 cfs and diversion rate was 10% to 20% of river flow, we recaptured trap efficiency test fish. Recaptures were minimal when river flow exceeded 1,500 cfs and diversion rate was less than 5%. During this time, many fish probably passed over Three Mile Falls Dam.

Methods for determining trap efficiency estimates were inadequate, as indicated by overestimation of hatchery migrants. Morning release could have impacted recapture of marked fish. Marked fish moved with the major diurnal pulses of migrating fish of their own species. If released upriver when fish were not moving, return of marked fish may have been reduced. Behavior of fish that are stressed from handling and release may be different than non-handled fish. The pooling effect of the dam may exacerbate behavioral differences and result in less efficient recapture of marked fish. We are unsure why coho salmon were recaptured in low numbers or not at all during most tests. Thedinga et al. (1994) addressed additional factors that may affect the loss of marked fish or low trap efficiency, including handling or predation mortality, poor mark retention or recognition, delayed migration, or trap avoidance. Bias in trap efficiency estimates needs to be addressed and reduced, if possible, to prevent over- or underestimation of abundance and survival. Conducting trap efficiency tests by species and by origin was our attempt at reducing bias. Means of reducing stress and experimental bias will be incorporated in our future studies.

The demarcation in trap efficiency estimates for subyearling fall chinook salmon prior to and on and after 1 June was due to a change in operations at West Extension Canal and a decrease in river flow. As Phase I pumping was initiated, canal withdrawals were reduced, and attraction velocities at the canal headgates diminished due to closure of the river-return pipe. River flow was about 35 cfs lower on 31 May and 1 June than on 30 May. Our estimates of migrant abundance were based on these separate efficiency estimates.

Outmigration Monitoring

A key difference in the collection of yearling species versus the collection of fall chinook subyearlings was the duration of migration. Fall chinook subyearlings arrived at the sampling facility two days after release and peaked on the third day. The outmigration was short and intense. Low subsampling rates (< 1% - 10%) during peak fish movement probably affected the precision of the estimated number collected. On the other hand, yearling fish, especially coho salmon, had a protracted outmigration. This allowed them to be captured mostly at subsample rates of 50% and greater, thus, increasing count accuracy.

Degree of smoltification (as measured by the smolt index) probably affected migration duration, magnitude, and timing for both hatchery and wild fish. The protracted outmigration of coho salmon may have been due to the stage of development at release. In fact, peak outmigration for coho salmon in early May coincided with their full transition to smolt status during this time frame as well as increased river flow. At release in February and March, most coho salmon were in the parr stage. For yearling spring chinook salmon, later outmigrants following the mid-March release may have been delayed because they had not completely smolted. The peak of wild spring chinook salmon at West Extension Canal in mid-April coincided with a 40% increase in smolted fish from the prior week. As subyearlings, these fish were mostly parr or intermediate when captured at Feed Canal in winter and early spring. Hatchery summer steelhead released in early April were also not fully smolted. These fish continued to be captured until early June (brand recovery information), whereas fully smolted steelhead released in mid-May passed by early June. The peak in wild summer steelhead in late April at RM 3 also coincided with a high proportion (70%) of smolted fish. Subyearling fall chinook salmon were 100% smolted at release and most moved out of the river system within three days after release. These fish also peaked at John Day Dam within ten days after release (Hayes et al. 1996). Remaining fish in the Umatilla basin moved out by mid-July (CTUIR and ODFW 1995).

The collection of wild spring chinook salmon and wild summer steelhead at Feed Canal during winter and early spring indicates that some portion of their populations rear in the lower river basin before migrating out of the basin later in the spring. Upper river trapping by CTUIR indicates that juvenile steelhead and chinook salmon move from tributaries in the fall (peaking in October), as water temperature declines, to overwinter in the mainstem river (Contor et al. 1995, 1996). Peak collection of wild spring chinook salmon in April and wild summer steelhead in April and May at RM 3 also corroborates findings from trapping by CTUIR where more of these fish species were captured during April and May in the upper Umatilla River (RM 79.5), Meacham Creek (RM 1.5), and Squaw Creek (RM 1; Contor et al. 1995, 1996).

Wild subyearling fall chinook salmon were caught as early as mid-May and as late as July. Wild fish dominated late-June catches at Westland and Maxwell canals and were also captured in July at RM 79.5 in 1994 and 1995 (Contor et al. 1995, 1996). The optimum thermal range for migration of subyearlings is 51° - 67°F (10.5°C - 19.4°C; Bell 1986). These temperatures were met in May and June at RM 14, and surpassed in July. At John Day Dam on the Columbia River, median (50%) passage for subyearling chinook from the mainstem and its tributaries is in late July, with 90% passage extending to late August and into September (Brege et al. 1996).

Trapping and hauling of subyearling fall chinook salmon at Westland Canal during summer low flows is currently critical to their successful migration. We estimated- 1,960 wild chinook salmon subyearlings were transported from Westland Canal to the lower river during the five days we sampled in late June. Given that juvenile fish were transported for 25 days in 1995 (CTUIR and ODFW 1995), a substantial number of wild chinook subyearlings are moving out of the basin in mid-summer. Since the effects of transport on juvenile fish survival are unknown, it seems prudent to increase instream flows during June and July (and reduce water temperature) to increase in-river survival.

Operators of irrigation canals should also be aware of the presence of these wild fish during midsummer. After our late-June sampling at Maxwell Canal, the canal was scheduled for dewatering to apply weed-control measures. Our information on the presence and abundance of wild subyearlings delayed their actions and prevented the accidental killing of these fish.

The presence of wild coho salmon subyearlings and fry from April to August corroborates findings from biological surveys in the upper river. Wild coho subyearlings were collected from upper basin tributaries (Moonshine, Mission, Cottonwood, and Coonskin creeks) from late June to late September (Contor et al. 1996), but not in the upper Umatilla River. Wild coho salmon were also collected in the summer at Westland Canal in 1995 (CTUIR and ODFW 1995).

The migration pattern of wild summer steelhead mimicked that of hatchery summer steelhead. Pulses of hatchery fish could have activated movement of wild fish, but the early peak of wild steelhead preceded the earliest hatchery steelhead release. Thus, early release of hatchery steelhead may mimic the natural emigration pattern. Trapping at RM 79.5 from May to June showed a peak in wild steelhead numbers toward late May (Contor et al. 1996) which also mimics the final migration peak at RM 3 for hatchery fish. However, the greater brand recoveries and migration rate of early-released steelhead suggest that early April is a better time to release hatchery fish. Brand recoveries of steelhead released in May were lower and migration for these fish was more delayed than April-released steelhead. Median passage for summer steelhead at John Day Dam from 1987 to 1993 was during mid-May and 90% passage was in early June (Brege et al. 1996).

Diel movement was slightly different for each species, but generally each moved after sunrise and near sunset. Differences were also seen in diel movement among months. These diel patterns of movement for juvenile salmon on the Umatilla River were slightly different for those at John Day Dam on the Columbia River. At John Day Dam, diel movements for yearling chinook salmon, coho salmon, and summer steelhead peaked near 2200 hours and before dawn (Brege et al. 1996). At West Extension Canal, yearling fish movement peaked immediately after sunrise and immediately before sunset. For subyearling chinook salmon on the Umatilla River, diel movement peaked primarily between sunrise and sunset, and most notably during mid-day in June. At John Day Dam, diel movement for subyearling chinook salmon peaked near 0500, 1400, and 2200 hours (Brege et al. 1996). Diel movement at major hydroelectric dams may be different than diel movement in the open river or at small irrigation dams. Ledgerwood et al. (1991) found that diel catches for subyearling and yearling chinook salmon and yearling coho salmon at Jones Beach, lower Columbia River, were highest during daylight hours.

Migrant Abundance and Survival

It is obvious from the indices of injury that the more time hatchery fish spend in the river, the poorer their condition. They become more susceptible to disease and scale loss and more vulnerable to predation, as evidenced by observed increases in BKD symptoms, descaling, and bird marks. The immediate and long-term survival of both hatchery and wild fish is probably adversely affected by diseases and parasites. Infections and infestations are exacerbated at higher water temperatures and transmissibility is enhanced under crowded and stressful conditions, particularly during outmigration, collection, and transport (Groberg and Onjukka 1992). Acclimation of fish may also affect their health. It is unknown whether the high incidence of black spot disease on wild fish affects their survival; a portion of all wild fish species were infected with the metacercaria.

Birds, particularly gulls and herons, affect juvenile salmonid survival. At Wanapum Dam on the Columbia River, an estimated 111,750 to 119,250 salmonids were consumed by gulls during 25 days of peak salmonid migration in 1982 (Ruggerone 1986). Juvenile salmonids migrating during the day in the Umatilla River are more susceptible to piscivorous birds. We observed numerous gulls perched on the dam sill at Three Mile Falls Dam, making many foraging attempts during peak outmigrations of juvenile salmon. Herons were also commonly observed in the early morning and nighttime hours at bypass facilities. We speculated that facility lighting at night may attract these birds and aide in their feeding. Although it may be difficult to deter the daytime activity of gulls, the nighttime activity of herons at bypass facilities could be reduced by elimination of overhead lighting.

The low survival estimate of subyearling fall chinook salmon may be attributed to poor river conditions, disease, and predation. Water temperature was near 70°F (21°C) in the midreach during the time of their release. By mid-June, maximum temperature at RM 14 was over 76°F (24.4°C) and mortality rose to about 10% at several sampling sites. Fish samples in July had high to moderate levels of bacterial gill disease and *Ich*. With temperatures near the lethal threshold for juvenile chinook salmon (77°F, 25°C) and possible exacerbation of diseases by high temperatures (Bell 1986), many weak and diseased fish could have perished. As river flows decrease in summer from increased irrigation withdrawals, upper tolerance levels for chinook salmon will continue to be approached and exceeded. These high thermal levels compound other stresses in the fish's life and affect swimming speeds and metabolism (Bell 1986). We noted by 8 June that many fall chinook subyearlings were thin and emaciated. In late spring 1993 at Westland Canal, we observed weakened subyearling chinook salmon near death on several rotary drum screens (Cameron et al. 1994).

Although predation was not estimated, nearly 1% of the subyearling fish collected at Westland and West Extension canals exhibited bird marks during some or all weeks of collection, and nearly 3% at Maxwell Canal. Squawfish predation may also have been a factor; adult-sized squawfish were more prevalent at West Extension Canal from June through August. The small size of these fish and their weakened condition may have resulted in increased vulnerability to both bird and fish predation. Northern squawfish tend to prey more on dead or moribund fish than live fish (Gadomski and Hall-Griswold 1992)

The low percent recovery of brands on fall chinook subyearlings (14.0%), expanded by trap efficiencies, corroborates our low survival estimate based on migrant abundance (17.7%). If collected number of fish or brand recoveries were underestimated due to bias in subsampling, then this would further reduce the estimate and index of survival. At John Day Dam, survival indices for Michigan-reared fish (5.8%) and Oregon-reared fish (4.4%; Hayes et al. 1996) were 2.3 and 3.8 times lower than brand recoveries at West Extension Canal.

The higher survival of two of the three marked fish groups released at RM 32.5 suggests survival may be higher in the lower than in the upper river. Reduced migration distance or less predation pressure may have been factors. We are uncertain why the first release group (red mark) was recaptured in such a low proportion relative to the other two release groups. Red markings may have made fish more visible to predators. Or, the red mark may have been misidentified as wounds at capture, although some examiners did note that red-marked fish seemed not to be as frequently recaptured as blue- and green-marked fish. More accurate counting of fish from the last two mark groups than the red mark group may have caused a discrepancy. The first group released on 2 June could have migrated (37.3 miles/day) to the sampling facility by 3 June, 29.2 miles downstream. The bulk of the outmigration passed through the facility on 3 June, forcing us to subsample as low as 0.04% for some hours. Expanded numbers could have been underestimated. The last two mark groups were sampled at much higher rates following 3 June.

Survival of yearling spring chinook salmon released in mid-March (66.6%; based on abundance estimates) was far greater than the survival index from brand recoveries (mean of 19.1%). We do not know why there was a discrepancy other than possible inaccurate brand reading early in the season or overestimated trap efficiencies. It appears that Bonneville-reared and later-released spring chinook salmon either survived better, were more easily captured, or brands were more accurately read (based on brand recoveries - 79.5%) than Umatilla-reared fish. Nontheless, survival indices from abundance estimates of Umatilla fish and from brand recoveries of Bonneville fish are far better than those for subyearling fall chinook salmon. River flow and temperature are also better for juvenile salmonids in March, April, and May than in June or July.

Sampling at different sites and for different time periods, and our inability to distinguish fall chinook salmon from spring chinook salmon after 7 April made accurate estimations of abundance and survival difficult. Because we did not expand 8-hour samples at Feed Canal to full 24-hour samples, abundance was necessarily underestimated. Fish sampled at Feed Canal on March 29th could have been resampled at West Extension Canal on March 30th or thereafter, causing overestimation. Biases in trap efficiency estimates resulted in huge disparities between lower river abundance estimates and upper river release numbers for all yearling species, once sampling was initiated at West Extension Canal. We will attempt to reduce these biases in the future.

The percent recovery of differentially clipped hatchery fish can also be used as an index of survival. Hatchery summer steelhead and subyearling spring chinook salmon had identical proportions of differential clips collected. This suggests there is no differential survival between AD or ventral-clipped and ADtventral-clipped fish. In fact, the ratio of clips for subyearling spring chinook salmon remained constant among all three collection sites. However, yearling spring chinook salmon and subyearling fall chinook salmon that were ADRV clipped were collected half as much as RV-clipped fish. For chinook salmon, AD-clipped fish are indicative of being coded-wire tagged. It is possible that the extra handling during coded-wire tagging may affect or reduce survival. Although the subyearling fall chinook salmon were not examined for clips on a consistent basis at West Extension Canal, they were at Westland and Maxwell canals where ADRV-clipped fish were greatly under-represented. The discrepancy in clips for yearling spring chinook salmon was particularly severe for fish collected at Feed Canal. Again, this discrepancy may have been due to inaccurate reading of fin clips early in the season.

Environmental Conditions

The relationship between peak in total fish movement and peak in river flow suggests that a sustained high river flow (> 4,000 cfs) does not sustain high fish movement. Only the initial rise in river flow appeared to push fish out. Outmigration studies in the Stanislaus River, California, also revealed that only the first pulse in flow from releases of stored water stimulated a substantial increase in juvenile chinook outmigration; the outmigration peak lasted only a few days (Demko 1996). Releases of stored water from McKay Reservoir to flush juvenile fish out may need to be pulsed rather than sustained to be most effective.

Instream flows are currently very low for fish migration during June, July, and August. With flows less than 100 cfs and water temperature exceeding 70°F (21.1°C) in the lower river, conditions are intolerable for juvenile salmonids. As specified in the Umatilla Basin Project Plan (USBR and BPA 1989), 250 cfs should be left in the river for fish passage. Extra flow could reduce water temperature and possibly eliminate the need for transport.

Phase I and Phase II pumping would benefit flows in the Umatilla River (USBR and BPA 1989) but Phase I pumping into West Extension Canal is currently non-operational during the summer and Phase II flow enhancement is not fully on-line.

Resident Fish and Predators

Dominant resident fish species found in the lower river were also found in the upper river (Contor et al. 1996). Although lamprey were once abundant in the Umatilla River, numbers have drastically declined over the years. The collection of juvenile and adult lamprey during our trapping indicates that lamprey are still in the river system.

The presence of northern squawfish at West Extension Canal indicates a possible predation concern, especially for subyearling species during summer months. Their diel activity in June (1500 hours) coincided with greatest movement of subyearling fall chinook salmon (1000 - 1400 hours).

PIT Tags

Monitoring the outmigration of juvenile salmonids with PIT tags would help answer fundamental questions regarding life history, migration characteristics, habitat utilization, passage problems, growth, and survival. This study and those related to hatchery and natural production evaluations provide an opportunity to test the feasibility of using PIT tags in the Umatilla River. PIT taas could replace current use of freeze brands. The advent of PIT tag detection at John Day Dam would improve monitoring of Umatilla fish in the Columbia River.

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LITERATURE CITED

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fish Passage Development and Evaluation Program, U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Boyce, R.R. 1986. A comprehensive plan for rehabilitation of anadromous fish stocks in the Umatilla River basin. Final report of Oregon Department of Fish and Wildlife to the Bonneville Power Administration, Portland, Oregon. Contract No. DE-A179-84P18008.

Brege, D.A., R.F. Absolon, and R.J. Graves. 1996. Seasonal and diel passage of juvenile salmonids at John Day Dam on the Columbia River. North American Journal of Fisheries Management 16:659-665.

Burnham, K.P., D.R. Anderson, G.C. White, C. Brownie, and K.H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5:1-437.

Cameron, W.A., S.M. Knapp, and B.P. Schrank. 1994. Pages 1-76 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Contor, C.R., E. Hoverson, and P. Kissner. 1995. Umatilla basin natural production monitoring and evaluation. Annual progress report 1993-1994 to Bonneville Power Administration, Portland, Oregon.

Contor, C.R., E. Hoverson, P. Kissner, and J. Volkman. 1996. Umatilla basin natural production monitoring and evaluation. Annual progress report 1994-1995 to Bonneville Power Administration, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation). 1984. Umatilla basin recommended salmon and steelhead habitat (hatchery and passage) improvement measures. Pendleton, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1995. Trapping and transportation of adult and juvenile salmon in the lower Umatilla River in northeast Oregon. Umatilla River Basin trap and haul program. Annual progress report to Bonneville Power Administration, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1989. Umatilla River subbasin - salmon and steelhead plan. Prepared for the Northwest Power Planning Council for Columbia Basin system' planning.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1990. Umatilla hatchery master plan. Prepared for the Northwest Power Planning Council, Portland, Oregon.

Demko, D.B. 1996. Effect of pulse flows on outmigration of juvenile chinook in the Stanislaus River. Abstract and talk presented at the Western Division American Fisheries Society Meeting, 14 July - 18 July 1996, Eugene, Oregon.

Efron,B. and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science l(1): 54-77.

Gadomski D.M. and J.A. Hall-Griswold. 1992. Predation by northern squawfish on live and dead juvenile chinook salmon. Transactions of the American Fisheries Society 121: 680-685.

Groberg, W.J. and S.T. Onjukka. 1992. Passage and survival of juvenile chinook salmon migrating from the Snake River basin. Proceedings of a Technical Workshop, University of Idaho, February 26-28, 1992.

Keefe, M.L., R.W. Carmichael, R.A. French, W.J. Groberg, and M.C. Hayes. 1993. Fish research project - Oregon. Umatilla hatchery monitoring and evaluation. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Keefe, M.L., R.W. Carmichael, S.M. Focher, W.J. Groberg, and M.C. Hayes. 1994. Umatilla hatchery monitoring and evaluation. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Knapp, S.M. and D.L. Ward. 1990. Pages 4-32 *in* A.A. Nigro, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at Three Mile Falls Dam, Umatilla River. Annual progress report to Bonneville Power Admininstration, Portland, Oregon.

Hayes, M.C., R.W. Carmichael, S.M. Focher, M.L. Keefe, G.W. Love. 1995. Pages 6-66 *in* Umatilla hatchery monitoring and evaluation. 1994 annual progress report to Bonneville Power Administration, Portland, Oregon.

Hayes, M.C., R.W. Carmichael, S.M. Focher, and R.W. Stonecypher, Jr. 1996. Pages 8-86 *in* Umatilla hatchery monitoring and evaluation. 1995 annual progress report to Bonneville Power Administration, Portland, Oregon.

Iwamoto, R.N., W.D. Muir, B.P. Sandford, K.W. McIntyre, D.A. Frost, J.G. Williams, S.G. Smith, and J.R. Skalski. 1994. Survival estimates for the passage of juvenile chinook salmon through Snake River dams and reservoirs. Annual report to the Bonneville Power Administration, Portland, Oregon.

Ledgerwood, R.D., F.P. Thrower, and E.M. Dawley. 1991. Diel sampling of migratory juvenile salmonids in the Columbia River Estuary. U.S. Department of Commerce, Fishery Bulletin 89(1): 69-78.

Muir, W.D., S.G. Smith, R.N. Iwamoto, D.J. Kamikawa, K.W. McIntyre, E.E. Hockersmith, B.P. Sandford, P.A. Ocker, T.E. Ruehle, J.G. Williams, and J.R. Skalski. 1995. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1994. Annual progress report prepared for the Bonneville Power Administration and the U.S. Army Corps of Engineers, Portland, Oregon.

Muir, W.D., S.G. Smith, E.E. Hockersmith, S. Achord, R.F. Absolon, P.A. Ocker, B.M. Eppard, T.E. Ruehle, J.G. Williams, R.N. Iwamoto, and J.R. Skalski. 1996. Survival estimates for the passage of the yearling chinook salmon and steelhead through Snake River dams and reservoirs, 1995. Annual progress report prepared for the U.S. Army Corps of Engineers and the Bonneville Power Administration, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1989. Fish screening criteria. National Marine Fisheries Service, Environmental and Technical Services Division, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1990. Fish passage facilities functional design guidelines and supplemental criteria. National Marine Fisheries Service, Environmental and Technical Services Division, Portland, Oregon.

NPPC (Northwest Power Planning Council). 1987. Columbia River basin fish and wildlife program (as amended). Northwest Power Planning Council, Portland, Oregon.

Ruggerone, G.T. 1986. Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River Dam. Transactions of the American Fisheries Society 115:736-742.

SAS Institute, Inc. 1990. SAS language: reference, version 6, first edition. Cary, North Carolina.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14: 837-851.

USBR (U.S. Bureau of Reclamation). 1988. Umatilla Basin Project -Planning report and final environmental impact statement. Statement Number FES 88-4, filed February 12, 1988.

USBR (U.S. Bureau of Reclamation) and BPA (Bonneville Power Administration). 1989. Umatilla basin project. Initial project workplan presented to the Northwest Power Planning Council, May 1989.

Table 1. Trap operation and sampling periods at six sampling sites on the lower Umatilla River, November 1994 - September 1995.

Site	River mile	Dates sampled	Trap check times	Trap operation
Lower River at RM 0.5	0.5	11/17-11/23/94	Hourly	Daylight hours
		11/26-12/13/94	Hourly	After sunset
Lower River at RM 1.8	1.8	1/13-1/31/95	Once/day	24 hours/day
Feed Canal	29.2	12/2/94-3/19/95	Hourly	Twilight-midnight
		3/20-3/28/95	Hourly	24 hours/day
West Extension Canal	3.0	3/30-6/10/95	Hourly	24 hours/day
		6/11-6/19/95	Once/day	24 hours/day
		7/1-8/6/95	Once/day	24 hours/day
		9/6-9/30/95	Once/day	24 hours/day
Maxwell Canal	14.8	6/22-6/29/95	Hourly	Daylight hours
Westland Canal	27.3	6/13,15,20,22,27/95	Once/day	Subsampled pond

Table 2. Recapture of hatchery and wild fish released for trap efficiency tests at the floating net trap in November and December 1994 and at the rotary-screw trap in January 1995, lower Umatilla River.

Date	Species[a]	Mark[b]	Number released	Days after release	Number recaptured	Trap efficiency
			Floating Trap Net (RM 0.3) - 8-Hour Sampling Period			
11/28/94	HCHS	R6	100	1	12	0.120
11/29/95	HCHS	G6	100	1	16	0.160
11/30/95	HCHS	B6	100	1	19	0.190
12/10/95	HCHS	B7	100	1	25	0.250
12/13/95	HCHS	G7	27	1	7	0.259
12/16/94	HCHS	P7	10	--	--	--
			Rotary-Screw Trap (RM 1.8) - 24-Hour Sampling Period			
1/24/95	HCHS	R8	24	1	4	0.167
1/26/95	HCHS	R15	52	1	7	0.135
1/26/95	WCHS	R16	9	1	1	0.111
1/27/95	HCHS	R14	26	1	10	0.385
1/28/95	HCHS	R13	16	1	3	0.188
1/30/95	HCHS	R11	8	1	1	0.125

[a] HCHS = hatchery subyearling spring chinook salmon, WCHS = wild subyearling spring chinook salmon.

[b] Mark colors: R = red, G = green, B = blue, P = purple; Mark locations: 1-16

Table 3. Recapture of hatchery fish released for trap efficiency tests, Feed Canal, Umatilla River, winter 1994 through spring 1995. TE = trap efficiency.

Date	Species[a]	Mark[b]	Number released	Days after release	Number recaptured	Cumulative TE
			8-Hour Sampling Period			
12/02/94	CHS	P6	32	1	1	0.031
12/05/94	CHS	R7	62	1	8	0.129
12/23/94	CHS	P7	19	1	19	1.000
3/15/95	CHS	G5	3	--	--	--
3/16/95	CHS	G6	123	9	1	0.008
3/17/95	CHS	G7	100	--	--	--
3/17/95	CHS	G8	90	--	--	--
3/19/95	CHS	G9	24	--	--	
3/19/95	CHS	G10	16	--	--	
3/19/95	CHS	G12	18		--	
2/22/95	COH	R5	31	1 30	5 1	0.193
2/23/95	COH	R7	113	1	21	0.186
2/24/95	COH	R8	211	1 7	20 1	0.100
2/27/95	COH	R5	100	1 17 25	10 1 1	0.120
2/28/95	COH	R4	100	1 4	8 1	0.090
3/01/95	COH	R3	96	1 5	6 1	0.073
3/02/95	COH	R2	105	1 2 4	6 1 1	0.076
3/03/95	COH	R1	107	1 2	6 1	0.065
3/04/95	COH	R9	101	1 2 12 13	9 1 1 1	0.119
3/05/95	COH	R10	101	1 10	6 1	0.069
3/06/95	COH	R11	102	1 2 7	5 1 1	0.069
3/07/95	COH	R12	61	1	5	0.082
3/08/95	COH	R13	37	1	2	0.054
3/09/95	COH	R14	26	1	4	0.154
3/11/95	COH	R15	25	1 2	4 1	0.200
3/12/95	COH	R16	17	1 2	1 1	0.118
3/13/95	COH	G1	13	3	1	0.077
3/14/95	COH	G2	12	--	--	--
3/15/95	COH	G5	22	--	--	
3/16/95	COH	G6	76	1 2	1 1	0.026
3/17/95	COH	G7	21	1	1	0.048
3/17/95	COH	G8	31	1	1	0.032
3/19/95	COH	G9	10	1	2	0.200
3/19/95	COH	G10	11	--	--	--
3/19/95	COH	G12	7	--	--	
			24-Hour Sampling Period			
3/20/95	CHS	G13	3	--	--	--
3/20/95	CHS	G14	41	3 4	1 1	0.049
3/21/95	CHS	G15	9	--	--	--
3/22/95	CHS	G16	16	1	1	0.063

Table 3. Continued.

Date	Species[a]	Mark[b]	Number released	Days after release	Number recaptured	Cumulative TE
3/23/95	CHS	B2	60	1 2 4	2 1 1	0.067
3/23/95	CHS	B4	57	1	4	0.070
3/24/95	CHS	B5	132	1 2 3	4 1 2	0.053
3/25/95	CHS	B6	110	--	--	--
3/26/95	CHS	B7	120	1	2	0.017
3/27/95	CHS	B8	46	1	2	0.043
3/28/95	CHS	B9	21	--	--	
3/20/95	COH	G13	15	1	2	0.133
3/20/95	COH	G14	22	1	2	0.091
3/21/95	COH	G15		1	1	0.040
3/22/95	COH	G16	[illegible]	--	--	
3/22/95	COH	B1	9	--		
3/23/95	COH	B2	5	--	--	--
3/23/95	COH	B4	15	1	1	0.067
3/24/95	COH	B5	24	1	2	0.083
3/25/95	COH	B6	26	1 2	2 2	0.154
3/26/95	COH	B7	10	1	5	0.500
3/27/95	COH	B8	19	1 2	2 1	0.158
3/28/95	COH	B9	19	1	2	0.105

[a] *COH = yearling coho salmon, CHS = subyearling and yearling spring chinook salmon.*

[b] *Mark colors: P = purple, R = red, G = green, B = blue; Mark locations: 1-16*

Table 4. Recapture of wild fish released for trap efficiency tests, Feed Canal, Umatilla River, winter 1994 through spring 1995. TE = trap efficiency.

Date	Species[a]	Mark[b]	Number released	Days after release	Number recaptured	Cumulative TE
			8-Hour Sampling Period			
12/05/94	CHS	R7	30	1	11	0.367
12/23/94	CHS	P7	8	1	4	0.500
2/24/95	STS	R8	10	1	2	0.200
2/28/95	STS	R7	7	--	--	--
3/02/95	STS	R5	2	--	--	--
3/03/95	CHS	R6	4	--	--	--
			24-Hour Sampling Period			
3/22/95	STS	G16	9	--	--	--
3/23/95	STS	B2	4	--	--	--
3/23/95	STS	B4	12	--	--	--
3/24/95	STS	B5	2	--		
3/25/95	STS	B6	4	--	--	--
3/26/95	STS	B7	3	--	--	--
3/27/95	STS	B8	3	--	--	--

[a] *STS = yearling summer steelhead, CHS = subyearling spring chinook salmon.*

[b] *Mark colors: R = red, P = purple, G = green, B = blue; Mark locations: 1-16*

Table 5. Recapture of hatchery fish released for trap efficiency tests, West Extension Canal, Umatilla River, spring 1995. TE = trap efficiency.

Date	Spec[a]	Mark[b]	Number released	Days after release	Number recaptured	Cumulative TE
3/31/95	CHS	B10	87	1 922	1 1 1	0.034
4/01/95	CHS	B12	26	--	--	--
4/03/95	CHS	B13	2	5	1	0.500
4/04/95	CHS	B16	3	--		--
4/05/95	CHS	01	17	--	--	--
4/06/95	CHS	02	4	1	1	0.250
4/07/95	CHS	04	24	1	4	0.167
4/08/95	CH	05	39	3 4	2 1	0.077
4/09/95	CH	06	88	1 3 5 8 10 12 19	3 2 1 1 1 1 1	0.108'
4/10/95	CH	07	32	1 18 25	1 3 1	0.163
4/11/95	CH	08	150	1 2 3 5 8 10 11	15 5 4 2 1 1 4	0.213
4/12/95	CH	09	100	12 3 4 510	12 11 1 1 1 4	0.303
4/13/95	CH	010	116	1 2 4 1 0	4 3 1 1	0.078
4/14/95	CH	012	100	1 2 3 4 5 6 7	10 2 4 6 2 2 1	0.273
4/15/95	CH	013	103	1 2 4 6 7 8 9	10 8 1 4 5 4 4	0.353
4/16/95	CH	014	193	14 5 6 7 810	15 2 7 4 4 3 10	0.235'
4/17/95	CH	015	113	15 6 7 8 911	9 5 410 13 3	0.307[c]
4/18/95	CH	016	167	12 3 4 5 818	7 6 8 4 2 5 2	0.201
4/19/95	CH	P1	200	1 3 5 6	3 2 410	0.095
4/20/95	CH	P2	197	1 2 3 13 23	18 7 4 1 1	0.157
4/21/95	CH	F4	219	1 2 5 13 20	21 5 3 1 1	0.140
4/22/95	CH	P5	201	1 2 6	22 13 4	0.194
4/23/95	CH	P6	133	1 2	5 2	0.053
4/24/95	CH	P7	239	6 22	3 3	0.025
4/25/95	CH	P8	187	--	--	--
4/26/95	CH	P9	226	--	--	
4/27/95	CH	P10	50	--		
4/28/95	CH	P12	205	--	--	--
4/29/95	CH	P13	109	1	2	0.018
4/30/95	CH	P14	203	--	--	
5/03/95	CH	R1	55	11	1	0.018
5/04/95	CH	R2	42	14	1	0.024
5/05/95	CH	R4	53	32	2	0.038
5/06/95	CH	R6	111	7	2	0.018
5/07/95	CH	R7	170	8	2	0.012
5/10/95	CH	R10	193	--	--	
5/11/95	CH	R12	55	1 425	2 2 1	0.090
5/12/95	CH	R14	204	2	1	0.005
5/13/95	CH	R15	200	2	2	0.01
5/14/95	CH	R16	142	--		--
5/15/95	CH	G1	172	--		--
5/16/95	CH	G2	126	1 2	1 1	0.016
5/17/95	CH	G4	105	1 2 3 6	14 1 1 8	0.228

Table 5. Continued.

Date	Spec[a]	Mark[b]	Number released	Days after release	Number recaptured	Cumulative TE
3/31/95	COH	B10	11	21	1	0.091
4/01/95	COH	B12	16	1 4	1 1	0.125
4/03/95	COH	B13	10	2	1	0.100
4/04/95	COH	B16	21	1 4	4 1	0.238
4/05/95	COH	01	14	--	--	--
4/06/95	COH	02	3	--	--	--
4/07/95	COH	04	13	1 16 18	3 1 4	0.615
4/08/95	COH	05	31	1 14	4 1	0.161
4/09/95	COH	06	95	--	--	--
4/10/95	COH	07	68	31 32	2 1	0.044
4/11/95	COH	08	17	--	--	--
4/12/95	COH	09	84	--	--	--
4/13/95	COH	010	84	31	1	0.012
4/14/95	COH	012	10	32	1	0.100
4/15/95	COH	013	16	--	--	--
4/19/95	COH	P1	4	--	--	--
4/22/95	COH	P5	197	--	--	--
4/23/95	COH	P6	96	1	1	0.010
4/24/95	COH	P7	215	--	--	--
4/25/95	COH	P8	61	--	--	--
4/26/95	COH	P9	179	--	--	--
4/27/95	COH	P10	54	--	--	--
4/28/95	COH	P12	101	--	--	--
4/29/95	COH	P13	145		--	--
4/30/95	COH	P14	207	--	--	--
5/01/95	COH	P15	200	--	--	--
5/02/95	COH	P16	203	--	--	--
5/03/95	COH	R1	212	--	--	--
5/04/95	COH	R2	215	--	--	--
5/05/95	COH	R4	206	2 3 6	2 12	0.024
5/06/95	COH	R6	216	4	2	0.009
5/07/95	COH	R7	88	4	1	0.011
5/08/95	COH	R8	206	--	--	--
5/09/95	COH	R9	205	--	--	--
5/10/95	COH	R10	242	4	1	0.004
5/11/95	COH	R12	207	6	1	0.005
5/12/95	COH	R14	206	5	1	0.005
5/13/95	COH	R15	211	--	--	--
5/14/95	COH	R16	201	1 3	2 3	0.025
5/15/95	COH	G1	200	1 3	4 1	0.025
5/16/95	COH	G2	209	--	--	--
5/17/95	COH	G4	202	1 2 4	9 1 1	0.054
7/05/95	COH	P6	14	8	1	0.071
4/14/95	STS	012	100	1 12	15 5	0.200
4/15/95	STS	013	131	1 23	7 2	0.069
4/16/95	STS	014	136	1 226	2 1 1	0.029

Table 5. Continued.

Date	Spec[a]	Mark[b]	Number released	Days after release	Number recaptured	Cumulative TE
4/18/95	STS	016	54	2	2	0.037
4/19/95	STS	P1	63	--	--	--
4/20/95	STS	P2	23	--	--	--
4/23/95	STS	P6	20	--	--	--
4/30/95	STS	P14	86	--	--	--
5/16/95	STS	G2	3	--	--	--
5/18/95	STS	G5	207	1 2 3 4 6	12 3 3 6 2	0.123
5/19/95	STS	G6	100	1 2 4 19	4 2 8 1	0.150
5/20/95	STS	G7	104	1 3	7 1	0.077
5/21/95	STS	G8	103	1 2 3 4	2 8 1 2	0.126
5/22/95	STS	G9	102	1 2	4 5	0.090
5/25/95	STS	G12	101	--	--	--
6/02/95	STS	B9	11	--	--	--
5/23/95	CHF	G9	494	1 3 5	308 1 1	0.628
5/24/95	CHF	G12	514	1 4 6	244 2 2	0.482
5/26/95	CHF	G15	500	1 2 4	256 12 1	0.539
5/27/95	CHF	G16	110	1 2 3	22 5 1	0.255
5/28/95	CHF	B1	155	1 2	58 4	0.400
5/29/95	CHF	B4	236	1 2 3 11 20	128 10 2 2 1	0.606
5/30/95	CHF	B6	293	1 2 3	163 3 2	0.573
5/31/95	CHF	B7	453	1 2 8	252 2 1	0.563
6/01/95	CHF	B8	423	1 7	17 2	0.044
6/03/95	CHF	B12	26	--	--	--
6/04/95	CHF	B14	364	1 2 3 4	14 5 3 1	0.064
6/05/95	CHF	815	406	1 2 3 4 5 6	55 4 4 4 1 1	0.170
6/06/95	CHF	B16	418	1 2 3 4	21 12 7 1	0.098
6/07/95	CHF	01	330	1 2 3	40 11 2	0.161
6/08/95	CHF	04	425	1 2 3 4	112 7 1 1	0.285
6/09/95	CHF	06	501	1 2 4 5 7	43 10 2 1 1	0.114
6/10/95	CHF	07	488	1 2 3 6	28 6 2 1	0.076
6/11/95	CHF	08	157	1	2	0.013
6/12/95	CHF	09	24	--	--	--
6/13/95	CHF	012	21	--	--	--
6/16/95	CHF	013	32	--	--	--

[a] *Spec = Species, COH = yearling coho salmon, CHS = yearling spring chinook salmon, CH = yearling chinook salmon, STS = yearling summer steelhead, CHF = subyearling fall chinook salmon.*

[b] *Mark colors: B = blue, 0 = orange, P = purple, R = red, G = green; Mark locations: 1-16.*

[c] *Additional recaptures:*

4/09/95	CH	06	27 34	1 1	0.131
4/16/95	CH	014	13 19 20 22 28	10 1 2 1 1	0.310
4/17/95	CH	015	12	4	0.342

Table 6. Recapture of wild fish released for trap efficiency tests, West Extension Canal, Umatilla River, spring 1995. TE = trap efficiency.

Date	Species[a]	Mark[b]	Number released	Days after release	Number recaptured	Cumulative TE
4/03/95	STS	B13	12	--	--	--
4/04/95	STS	B16	7	1	2	0.286
4/05/95	STS	01	15	--	--	--
4/06/95	STS	02	14	1	1	0.071
4/07/95	STS	04	17	1 2	4 2	0.353
4/08/95	STS	05	50	1	5	0.100
4/12/95	STS	09	26	2	1	0.038
4/13/95	STS	010	22	--	--	--
4/14/95	STS	012	6	3	1	0.167
4/15/95	STS	013	8	--	--	--
4/23/95	STS	P6	10	--	--	--
4/30/95	STS	P14	76	--	--	--
4/06/95	CHS	02	34	--	--	--
4/07/95	CHS	04	38	1	2	0.053
4/08/95	CHS	05	39	--	--	--
4/13/95	CHS	010	13	1	1	0.077
4/15/95	CHS	013	4	--	--	--
4/11/95	COH	08	31	--	--	--
7/05/95	COH	P6	2	--	--	--
7/05/95	CHF	P6	8	--	--	--

[a] *STS = yearling summer steelhead, CHS = yearling spring chinook salmon, COH = subyearling coho salmon, CHF = subyearling fall chinook salmon.*

[b] *Mark colors: B = blue, 0 = orange, P = purple; Mark locations: 1-16.*

Table 7. Total capture of juvenile salmonids at six sampling sites on the lower Umatilla River, November 1994 - September 1995 (sites are ordered chronologically). Standard deviation of mean FL is in parentheses.

Site[a], Species[b]	Origin	Age	Mean FL(mm)	Number collected[c]	Number released[d]	Release date[e]	Percent of release
River Mile 0.5							
CHS	H	0^+	155.5(26.1)	**1,472**	**378,225**	11/15/94	**0.40%**
CHS	W	0^+	**99.2 (7.6)**	**9**	--	--	--
Total Collected				***1,481***			
River Mile 1.8							
CHS	H	0^+	136.4(13.8)	149	**378,225**	11/15/94	**0.04%**
CHS	W	0^+	100.8(10.2)	**24**	--	--	--
STS	W	1^{+f}	133.9(18.1)	10	--	--	--
Total Collected				*183*			
Feed Canal							
CHS	H	0^+	129.8(11.7)	**186**	**378,225**	11/15/95	**0.05%**
CHS	H	1^+	167.8(26.8)	**6,652**	**441,231**	03/13/95	**1.50%**
COH	H	1^+	126.7(10.0)	**2,801**	**322,858**	03/01/95	0.90%
STS	H	1^+		1	--	--	--
CHS	**w**	**o+**	100.8(10.5)	**170**	--	--	--
COH	W	0^+	87.8(12.9)	**79**	--	--	--
STS	W	1^{+f}	141.9(33.4)	**149**	--	--	--
Total Collected				***10,038***			
West Extension Canal							
CHS	H	1^+	---	**266**	**441,231**	03/13/95	**0.06%**
CH	H	1^+	**168.5(20.6)**	**220,075**	**549,880**	04/21/95	40.00%
CHF	H	0^+	88.7(14.7)	**82,089**	2,466,298	05/31/95	**3.30%**
COH	H	1^+	142.7(14.1)	**407,609**	1,514,266	04/07/95	**26.90%**
STS	H	1^+	214.5(15.9)	**17,786**	**146,463**	05/12/95	**12.10%**
CHS	W	1^+	113.1(19.2)	1,695	--	--	--
CHF	W	0^+	68.1(15.3)	111	--		--
COH	W	0^+	66.3(29.1)	**237**	--	--	--
STS	W	1^{+f}	179.0(24.7)	**3,316**		--	--
Total Collected				**733,184**			
Maxwell Canal							
CHF	H	0^+	100.7(8.2)	**718**	**2,466,298**	05/31/95	**0.03%**
COH	H	1^+	129.1(15.6)	**15**	--	--	--
STS	H	1^+	**215.0**	1	--	--	--
CHF	W	0^+	74.5(12.7)	**335**	--		--
COH	**w**	0^+	78.3(16.9)	7	--	--	--

Table 7. Continued.

Site[a], Species[b]	Origin	Age	Mean FL(mm)	Number collected[c]	Number released[d]	Release date[e]	Percent of release
Maxwell Canal (continued)							
STS	W	1^{+f}	144.4(37.9)	9	--	--	--
Total Collected				***1,085***			
Westland Canal							
CH	H	1^+	240.0	1	--	--	--
CHF	H	0^+	92.9(6.1)	2,385	2,466,298	05/31/95	0.10%
COH	H	1^+	138.3(16.2)	4	--	--	--
STS	H	1^+	201.C(18.1)	4	--	--	--
CHF	W	0^+	73.9(13.9)	330	--	--	--
COH	W	0^+	67.6(21.5)	5	--	--	--
STS	W	1^{+f}	201.5(44.0)	4	--	--	--
Total Collected				**2,733**			

[a] *see Table 1* for *periods of collection.*

[b] *CHS* = spring *chinook salmon, CHF = fall chinook salmon, CH = combined spring and fall chinook salmon,* *COH = coho salmon, STS = summer steelhead.*

[c] *Number collected* was *expanded* for *subsampled and non-sampled times during 24-hour collection at Feed Canal and West Extension Canal.*

[d] *Number released is the number of hatchery fish released during* or *before sampling at the specific site.*

[e] *Release date is the date of last* release *for the designated group of fish.*

[f] *Age of wild summer steelhead includes* 1^+, 2^+, *and possibly* 3^+ *fish.*

Table 8. Fish collections from the juvenile fish holding pond at Westland Canal during Trap and Haul operations, June 1995.

Date	Sampling[a] location	Sample weight (lb)	Total no. fish	No.[b] HCHF	No.[b] WCH	No.[b] HSTS	No.[b] HCOH	No.[b] WSTS	No.[b] RSS	No.[b] SKR	No.[b] SQF	No.[b] CHM	No.[b] TAD
6/13	TM	2.5	125	119	4	0	1	0	1	0	0	0	0
6/13	TL	2.2	110	107	3	0	0	0	0	0	0	0	0
6/13	TR	2.2	126	124	2	0	0	0	0	0	0	0	0
6/13	BM	1.7	95	91	4	0	0	0	0	0	0	0	0
6/13	BL	1.6	73	70	3	0	0	0	0	0	0	0	0
6/13	BR	1.7	74	70	3	0	0	0	1	0	0	0	0
Total:		11.9	603	581	19	0	1	0	2	0	0	0	0
Percent of sample:				96.3	3.2	0	0.2	0	0.3	0	0	0	0
No. fish per transport lb:[c]				48.8	1.6	0	0.1	0	0.2	0	0	0	0
6/15	TM	5.6	283	265	15	0	0	1	1	0	0	0	1
6/15	TL	5.5	255	221	29	1	0	1	1	2	0	0	0
6/15	TR	6.4	322	290	27	1	0	0	1	0	1	2	0
6/15	BM	3.9	193	167	26	0	0	0	0	0	0	0	0
6/15	BL	1.5	80	72	8	0	0	0	0	0	0	0	0
6/15	BR	6.2	286	259	22	0	0	2	1	1	1	0	0
Total:		29.1	1419	1274	127	2	0	4	4	3	2	2	1
Percent of sample:				89.8	9.0	0.1	0	0.3	0.3	0.2	0.1	0.1	0.1
No. fish per transport lb:[c]				43.8	4.4	0.1	0	0.1	0.1	0.1	0.1	0.1	0.03

[a] *Location within crowded portion of pond: TM = top-middle, TL = top-left, TR = top-right, BM = bottom-middle, BL = bottom-left, BR = bottom-right.*

[b] *HCHF = hatchery subyearling fall chinook salmon, WCH = wild chinook salmon, HSTS = hatchery summer steelhead, HCOH = hatchery coho salmon, WSTS = wild summer steelhead, RSS = redside shiner, SKR = sucker, SQF = squawfish, CHM = chislemouth chub, TAD = tadpole.*

[c] No. *fish per transport lb. is the number of fish per species within each pound of total fish being transported.*

Table 8. Continued.

Date	Sampling location[a]	Sample weight (lb)	Total no. fish	No. HCHF	No. WCH	No. HSTS	No. HCOH	No. WSTS	No. RSS	No. SKR	No. SQF	No. CHM	No. TAD
6/20	MDM	2.2	84	73	6	0	1	0	2	0	1	0	1
6/20	MDL	2.2	86	77	7	1	0	0	0	1	0	0	0
6/20	MDR	2.2	110	92	16	0	0	0	0	0	0	1	1
Total:		6.6	280	242	29	1	1	0	2	1	1	1	2
Percent of sample:				86.4	10.4	0.4	0.4	0	0.7	0.4	0.4	0.4	0.7
No. fish per transport lb:				36.7	4.4	0.2	0.2	0	0.3	0.2	0.2	0.2	0.3
6/22	MDM	2.5	76	49	21	0	0	0	0	3	0	2	1
6/22	MDL	2.6	74	50	18	0	0	0	0	4	0	1	1
6/22	MDR	4.2	162	132	26	0	0	0	1	1	2	0	0
Total:		9.3	332	231	65	0	0	0	1	8	2	3	2
Percent of sample:				74.0	20.8	0	0	0	0.3	2.6	0.6	1.0	0.6
No. fish per transport lb:				25.0	7.0	0	0	0	0.1	0.9	0.2	0.3	0.2
6/27	MDM	0.8	42	16	26	0	0	0	0	0	0	0	0
6/27	MDL	0.5	26	5	19	0	0	0	1	0	1	0	0
6/27	MDR	1.0	70	20	50	0	0	0	0	0	0	0	0
Total:		2.3	138	41	95	0	0	0	1	0	1	0	0
Percent of sample:				29.7	68.8	0	0	0	0.7	0	0.7	0	0
No. fish per transport lb:				17.8	41.3	0	0	0	0.4	0	0.4	0	0

[a] *Location within crowded portion of pond: MDM = middepth-middle, MDL = middepth-left, MDR = middepth-right.*

Table 9. Scale samples collected from wild juvenile salmonids at sampling sites on the Umatilla River, December 1994 - July 1995.

Species[a]	Site	Number	Length(mm) Mean	Min.	Max.	Dates collected
STS	River Mile 1.8	9	134.0	116.0	172.0	1/24/95-1/29/95
CHS	River Mile 1.8	1	103.0	--	--	1/28/95
STS	Feed Canal	146	144.0	73.0	249.0	12/05/95-3/28/95
STS	WEID Canal[b]	286	183.0	94.0	335.0	4/05/95-6/04/95
COHO[c]	WEID Canal	26	116.6	70.0	178.0	4/09/95-7/03/95

[a] STS = summer steelhead, CHS = spring chinook salmon, COHO = coho salmon.
[b] WEID Canal = West Extension Irrigation District Canal.
[c] Coho salmon collected included several hatchery coho.

Table 10. Collection of freeze-branded juvenile salmonids at Feed, West Extension, Maxwell, and Westland canals, Umatilla River, March - June 1995.

Species[a], Brand	Site, Number	Site, Number	Site, Number	Site, Number	Total number	Expanded number[c]	Number released	Percent of release Total	Percent of release Expanded
STS	Feed	WEID[b]	Maxwell	Westland					
RAB1	--	187	0	0	187	2,370	8,134	2.3	29.1
RAB2	--	122	0	0	122	1,544	7,771	1.6	19.9
RAB4	--	89	0	0	89	1,127	8,908	1.0	12.6
CHS	Feed	WEID	Maxwell	Westland					
RAB1	11	25	0	0	36	759	4,910	0.7	15.5
RAB4	3	5	0	0	8	183	4,436	0.2	4.1
LAB1	26	3	0		29	1,169	5,176	0.6	22.6
LAB3	32	1	0	0	33	1,402	4,975	0.7	28.2
LAB2	36	0	0	0	36	1,565	5,063	0.7	30.9
LAB4	15	2	0	0	17	688	5,133	0.3	13.4
RAB3	--	422	0	0		4,489	5,137	8.2	87.4
RAB2	--	328	0	0	422 328	3,489	4,878	6.7	71.5
CHF	Feed	WEID	Maxwell	Westland					
LAL1	--	144	3	16	163	1,250	10,666	1.5	11.7
LAL3	--	152	1	12	165	1,312	10,325	1.6	12.7
RAL4	--	138	1	6	145	1,186	10,179	1.4	11.7
RAL1	--	444	3	9	456	1,292	10,172	4.5	12.7
RAL3	--	173	1	10	184	1,490	10,183	1.8	14.6
LAL4	--	143	0	11	155	1,233	10,254	1.5	12.0
LAE2	--	220	2	3	225	1,885	10,374	2.2	18.2
RAL2	--	208	0	6	214	1,764	10,250	2.1	17.2
RAE2	--	574	1	7	582	1,824	10,439	5.6	17.5
LAL2	--	152	0	3	155	1,302	11,104	1.4	11.7

[a] *STS = yearling summer steelhead, CHS = yearling spring chinook salmon, CHF = subyearling fa17 chinook salmon.*

[b] *WEID = West Extension Irrigation District Canal.*

[c] *Number expanded is the total number collected adjusted by weighted trap efficiency for the period(s) branded fish were collected.*

Table 11. **Fin clips documented on juvenile salmonids collected at six sampling sites on the Umatilla River, November 1994 - June 1995.**

Species[a], Clip	Site, Number	Site, Number	Site, Number	Site, Number	Site, Number	Site, Number	Total number	Number marked released	Percent of rel.[b]
STS 1^+	**RM1.8**	**RM0.5**	**Feed**	WEID[c]	**Maxwell**	Westland			
AD	--	--	--	**2,292**	**0**	**0**	**2,292**	**88,579**	0.026
ADLV	--	--	--	1,569	0	0	1,569	57,884	0.027
CHS 1^+									
RV	--	--	4,533	**141**	**0**	**0**	4,674	554,316	0.008
ADRV	--	--	671	123	--	--	794	209,707	0.004
CHS 0+									
RV	**13**	**130**	19	--	--	--	162	32,195	0.005
ADRV	161	1,421	249	--	--	--	1,831	346,030	0.005
CHF 0^+									
RV	--	--	--	37	709	2,207	2,953	1,996,673	0.001
ADRV	--	--	--	6	9	164	179	469,625	0.0004

[a] *STS 1^+ = yearling summer steelhead, CHS 1^+ = yearling spring chinook salmon, CHS 0^+ = subyearling spring chinook salmon, CHF 0 = subyearling fall chinook salmon.*

[b] *rel. = release*

[c] *West Extension Irrigation District Canal.*

Table 12. Estimates of weighted trap efficiency and migrant abundance (+ 95% confidence limits) for hatchery and wild juvenile salmonids passing Feed and West Extension canals and two in-river trap sites on the lower Umatilla River, November 1994 - June 1995.

Site Species[a]	Origin	Age	Trap efficiency[b]	Abundance estimate	95% Confidence interval[c]
River Mile 0.5					
CHS	H	0^+	0.181	8,133	± 1,721
River Mile 1.8					
CHS	H	0^+	0.198	752	± 314
CHS	W	0^+	0.111	216	± 191
Feed Canal					
CHS	H	0^+	0.241	772	± 291
CHS	H	1^+	0.023	289,217	± 131,545
COHO	H	1^+	0.094	29,798	± 4,517
CHS	W	0^+	0.395	430	± 220
STS	W	1^{+d}	0.033	4.515	± 5.951
West Extension Canal					
CHS	H	1^+	0.055	4,836	±6,249
CH	H	1^+	0.094	2,341,223	±195,644
COHO	H	1^+	0.012	33,967,417	
STS	H	1^+	0.079	225,139	± 42,715
[e]CHF_1	H	0^+	0.538	78,095	
[e]CHF_2	H	0^+	0.117	342,513	± 30,588
STS	W	1^{+d}	0.061	54,361	± 32,810
CHS	W	1^+	0.023	73,696	± 117,991

[a] *CHS = spring chinook salmon, COHO = coho salmon, STS = summer steelhead, CH = combined yearling spring and fa77 chinook salmon, CHF = subyearling fa17 chinook salmon.*

[b] *Trap efficiency was based on the total number of fish recaptured from the total number of fish released.*

[c] *Variance estimates for 95% confidence intervals were derived from the Bootstrap method.*

[d] *Age of wild summer steelhead includes 1^+, 2^+, and possibly 3^+ fish.*

[e] *Abundance estimates were derived separately for two groups of CHF collected before and on/after 1 June. Variance estimates were summed for the overall confidence interva7.*

Table 13. Release and recapture of marked fish for estimation of survival of subyearling fall chinook salmon in the lower Umatilla River, June 1995. Release occurred at RM 32.5 and recapture occurred at RM 3.0.

Species	Date	Mark color	Number marked	Number recaptured	Expanded recapture[a]	Percent Recapture collected	Percent Recapture expanded
CHFO+	6/02/96	Red	1,423	14	120	0.01	8.43
CHFO+	6/05/96	Green	562	41	350	0.07	62.28
CHFO+	6/06/96	Blue	679	41	350	0.06	51.55

[a] *Expanded recapture is the number recaptured adjusted for weighted trap efficiency (0.117) at RM 3 during the time of capture of these fish.*

Table 14. Number and mean length (mm) of resident fish captured at six sampling sites on the Umatilla River, November 1994 - September 1995. Length is expressed as a mean in mm.

	WEID CANAL		FEED CANAL		MAXWELL CANAL		WESTLAND CANAL		FYKE NET		SCREW TRAP	
COLLECTION PERIOD	03/30-09/30/95		12/02/94-03/28/95		06/22-06/29/95		06/13-06/27/95		11/17-12/13/94		01/13-01/31/95	
SPECIES	# COLL	Length	# COLL	Length	# COLL	Length	# COLL	Length	# COLL	Length	# COLL	Length
Unidentified Bass spp.	862	55 1	2	---	0	---	0	---	0	---	0	---
Bridgelip Sucker	1093	232.0	494	---	7	215 3	10	195 1	0	---	0	---
Bullhead spp.	298	84 1	5	---	3	63 0	0	---	0	---	12	---
Chiselmouth	1610	220 4	216	199 9	1	---	8	146 4	48	---	72	---
Crappie spp.	214	66 9	0	---	0	---	0	---	3	---	1	---
Crawfish	0	---	12	---	0	---	0	---	0	---	0	---
Carp	9	218.3	0	---	0	---	0	---	0	---	1	---
Dace	171	59.0	1046	49 5	5	47 2	0	---	1	---	5	---
Pacific Lamprey	35	376 7	0	---	0	---	0	---	3	---	3	---
Largemouth Bass	6	88 7	0	---	0	---	0	---	2	---	0	---
Largescale Sucker	113	239 5	22	---	12	226 6	3	230 0	0	---	0	---
Peamouth	5	---	69	---	1	---	0	---	3	---	0	---
Yellow Perch	9	127 6	5	---	0	---	0	---	8	---	0	---
Redside Shiner	615	78.4	846	60 7	105	79.9	11	85 1	81	---	60	---
Sculpin spp.	0	---	3	---	0	---	0	---	0	---	0	---
Unidentified Sucker	178	157 1	107	---	4	176 5	0	---	287	---	348	---
Smallmouth Bass	445	112 8	1	---	1	---	0	---	1	---	5	---
Unidentified Shiners	8	59 5	163	57 6	0	---	0	---	0	---	0	---
Northern Squawfish	639	199 2	451	87 0	11	174 8	6	127 8	35	---	31	210 7
Sunfish	7	117 3	0	---	0	---	0	---	0	---	0	---
Tadpole	47	96 4	14	---	6	123 2	7	108 3	0	---	1	---
Whitefish	1	---	13	---	0	---	0	---	0	---	2	---
TOTAL	6365	---	3469	---	156	---	45	---	472	---	541	---

Table 15 . Observations of avian fish predators recorded at or near West Extension Canal from April through early June and at Feed Canal in late-March 1995.

Avian predator	Number at West Extension Canal (April - early June)	Number at Feed Canal (late March)
Seagull	1129	2819
Great blue heron	122	5
Heron	118	0
Blue crowned heron	76	0
American bittern	18	0
Cormorant	61	0
Belted kingfisher	1	1
Osprey	10	0
Merganser	0	5

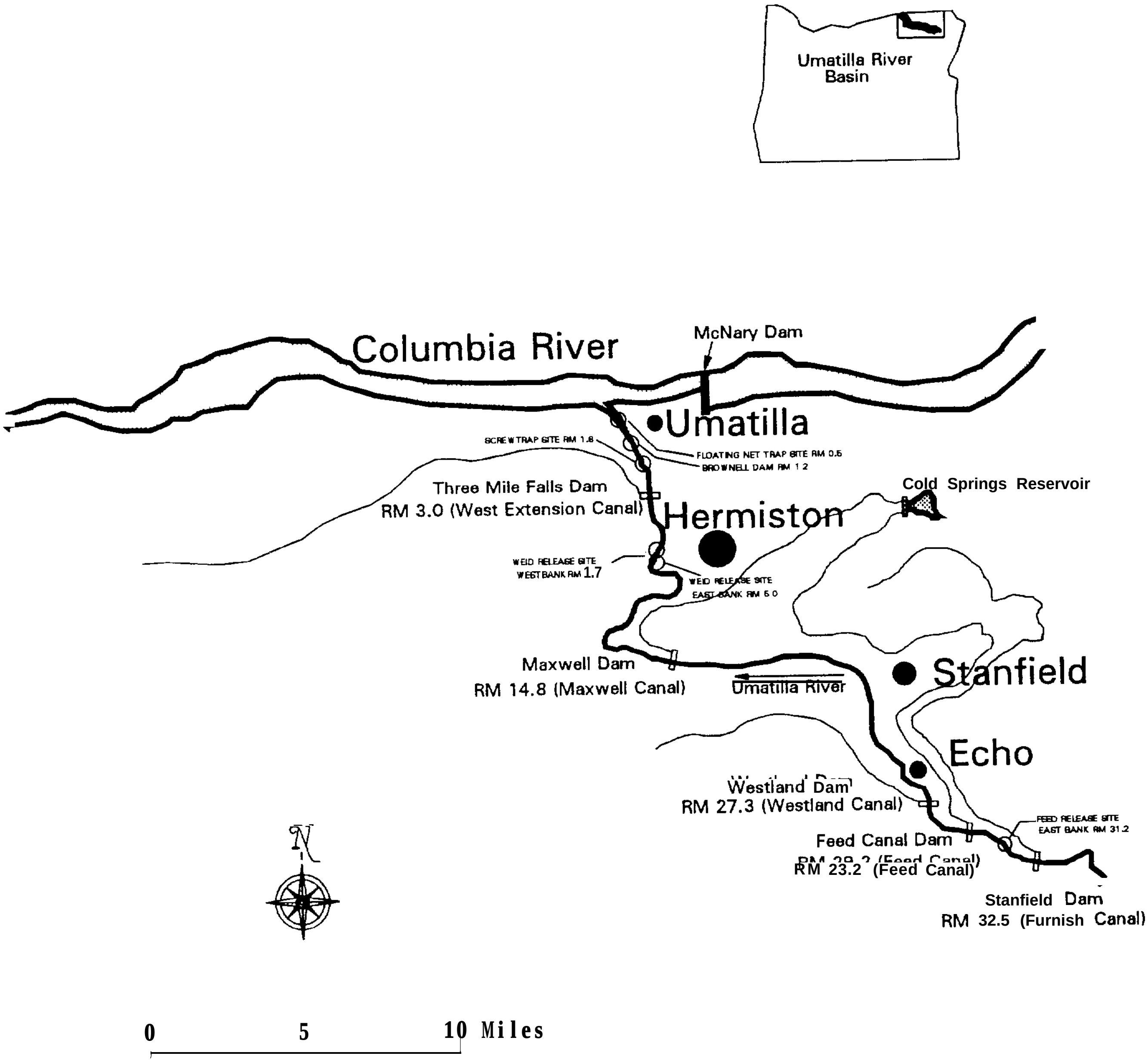
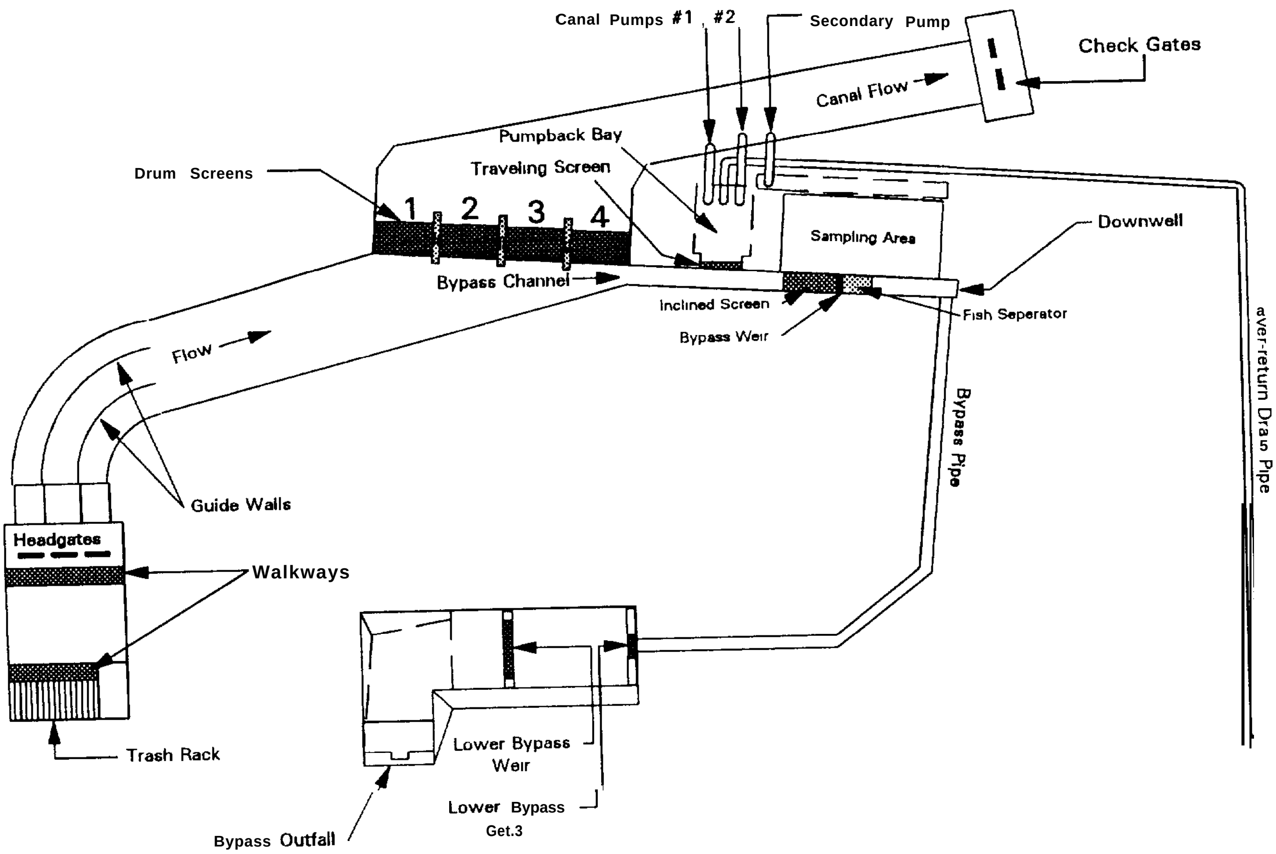


Figure 1. Study sites and trap efficiency release sites on the lower Umatilla River, Oregon, November 1994 - September 1995.



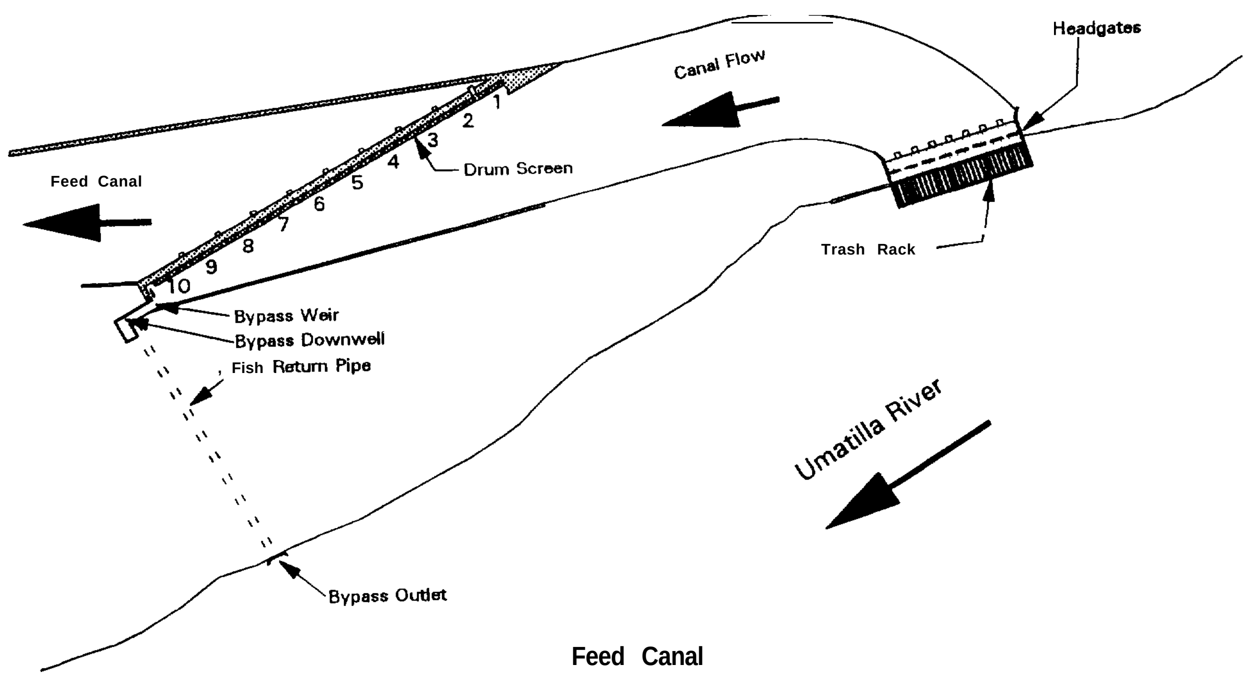


Figure 2. Schematic of the West Extension Canal juvenile fish bypass and sampling facility, and the Feed Canal bypass facility, Umatilla River.

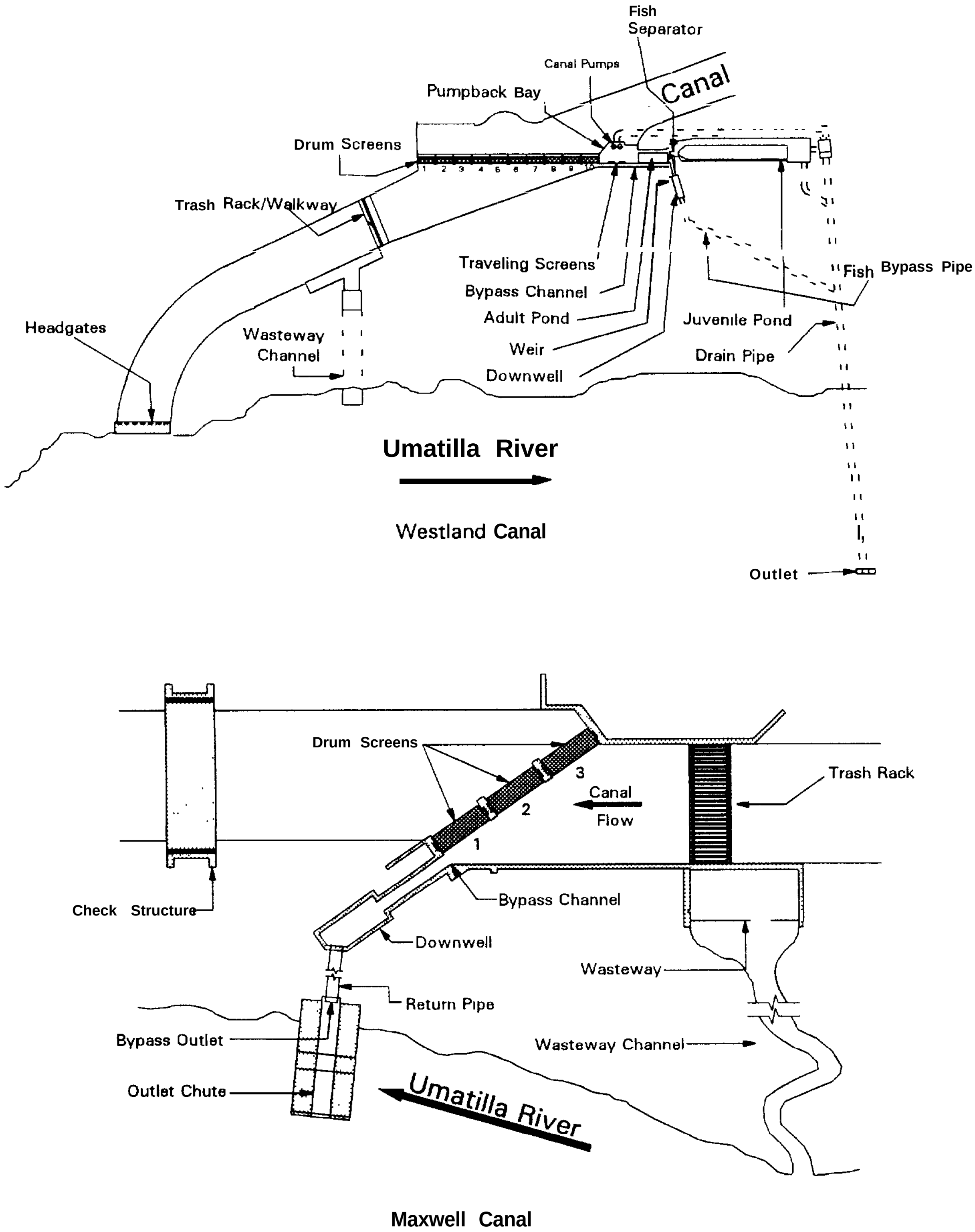


Figure 3. Schematic of the Westland Canal juvenile fish bypass and collection facility and the Maxwell Canal bypass facility, Umatilla River.

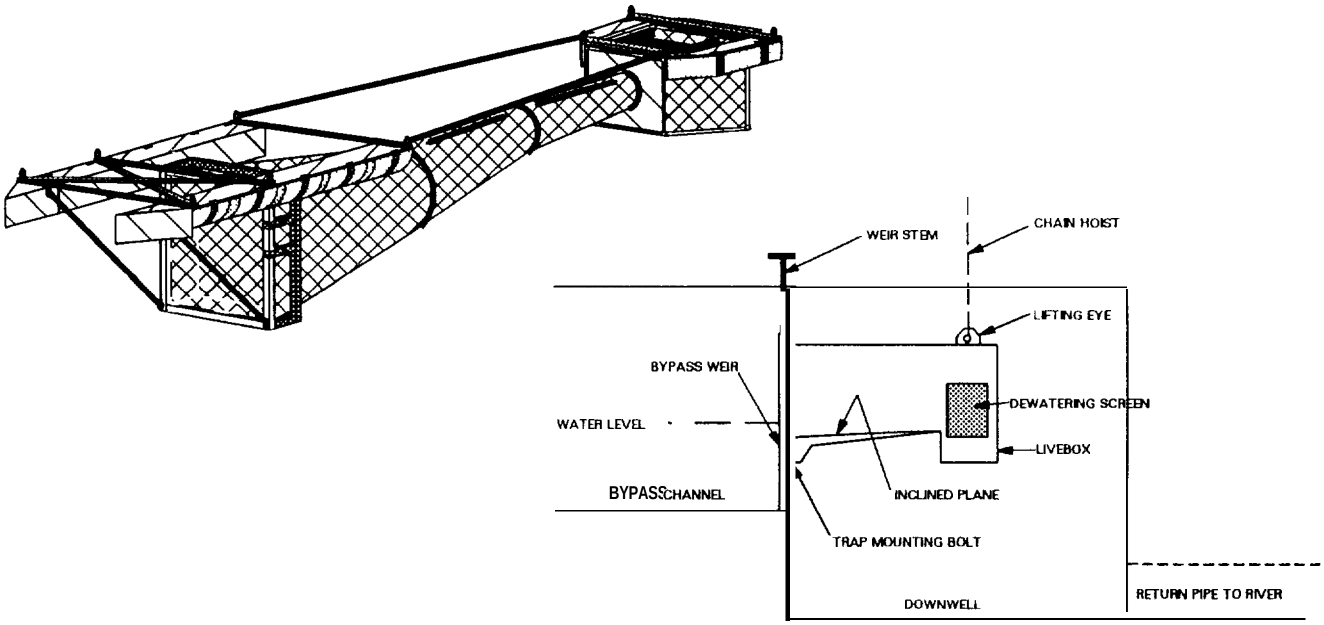


Figure 4. Floating net trap and inclined plane trap used for fish collection at in-river and bypass facility sampling sites.

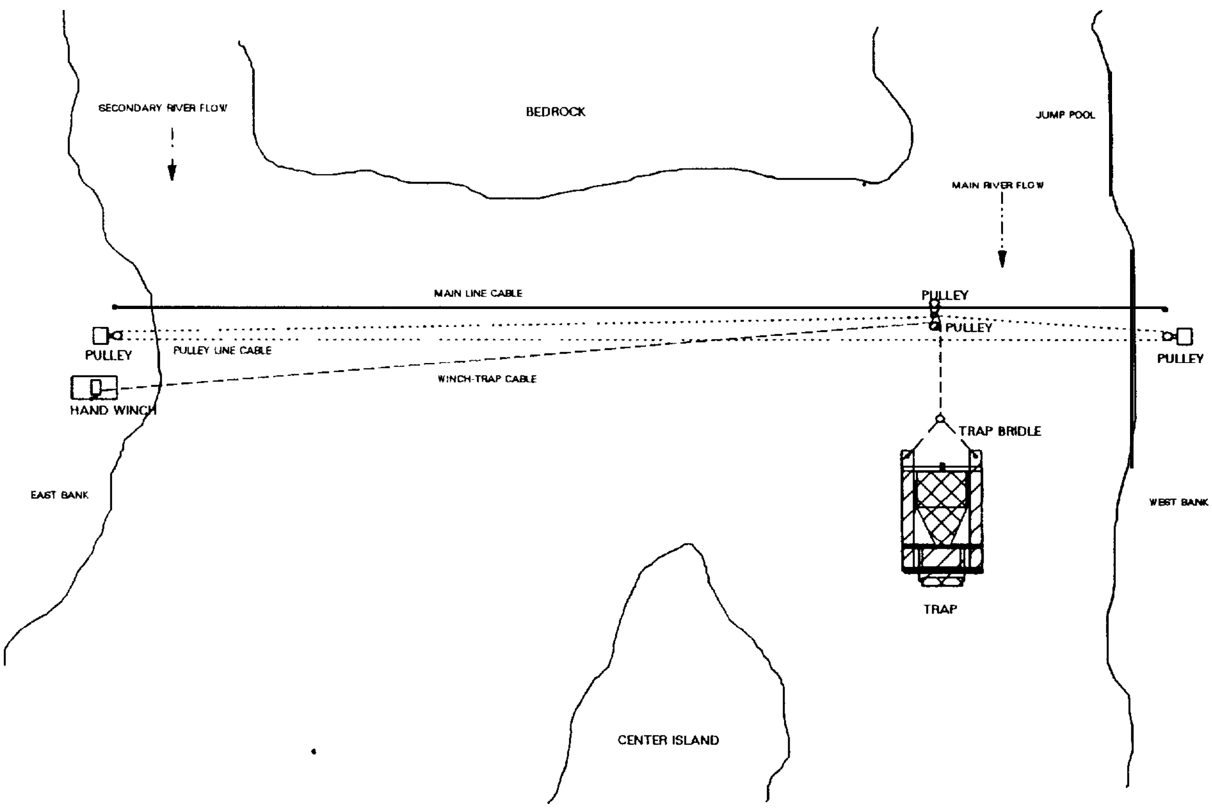


Figure 5. Rotary-screw trap and anchoring system, River Mile 1.8, Umatilla River.

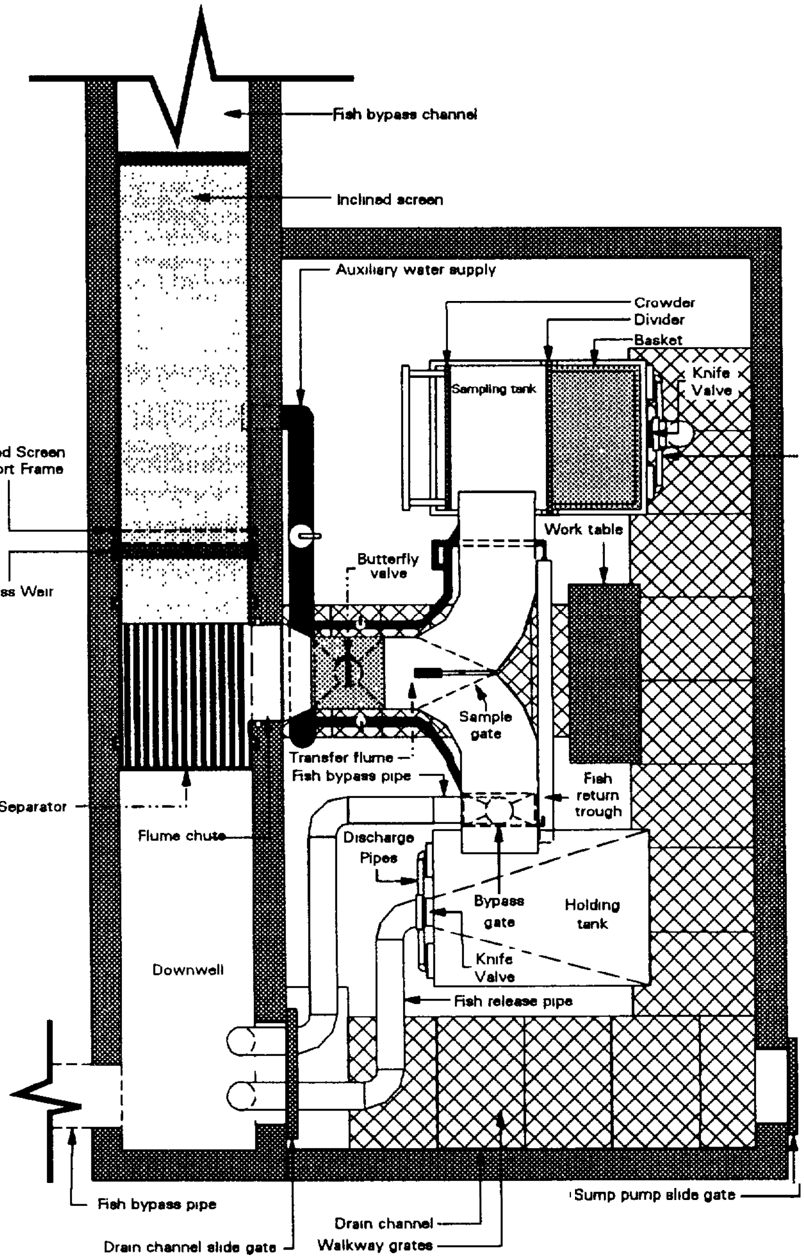


Figure 6. Schematic of the West Extension Canal juvenile fish sampling facility, Umatilla River.

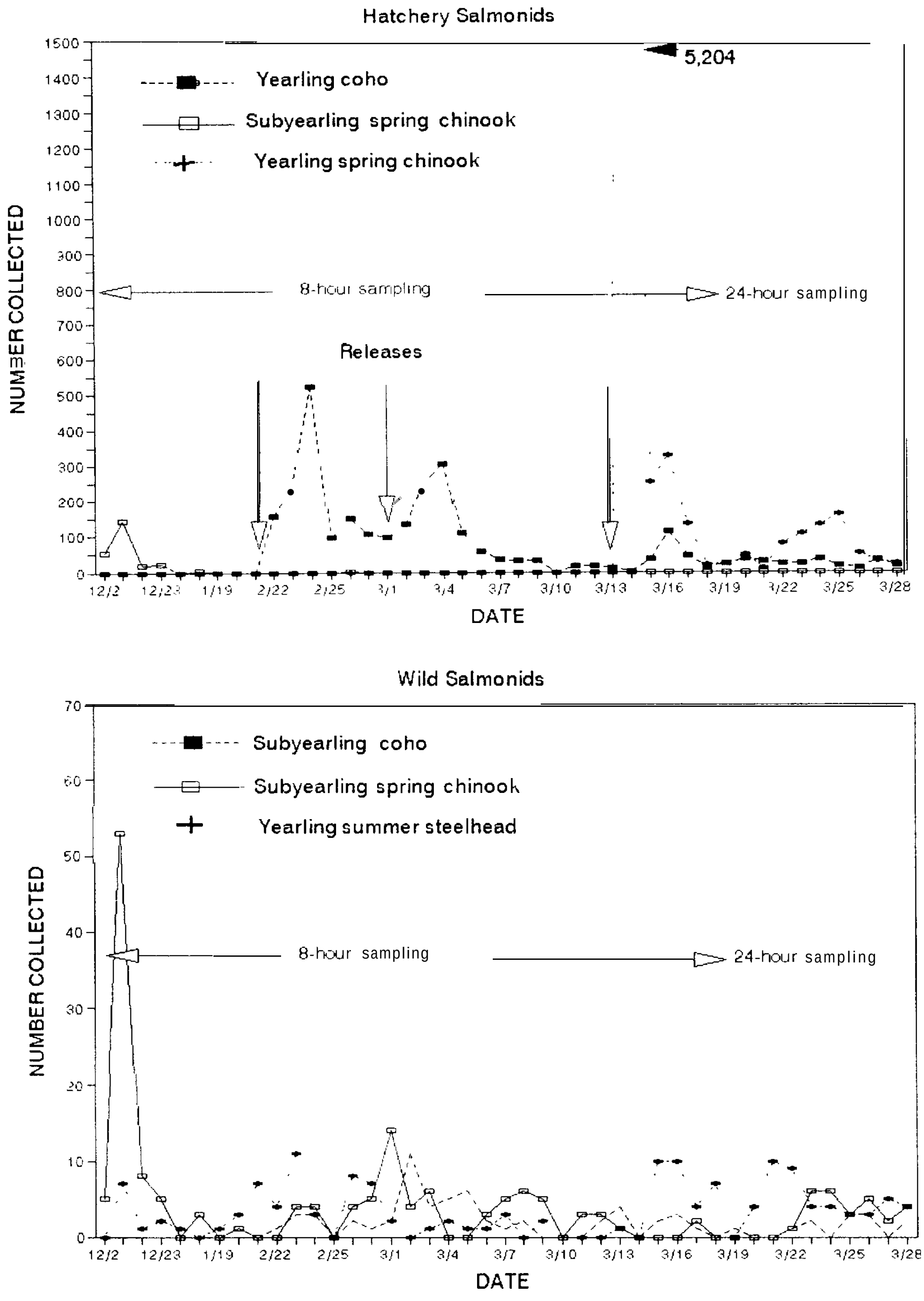


Figure 7. Numbers of hatchery and wild juvenile salmonids collected at Feed Canal, Umatilla River, December 1994 - March 1995.

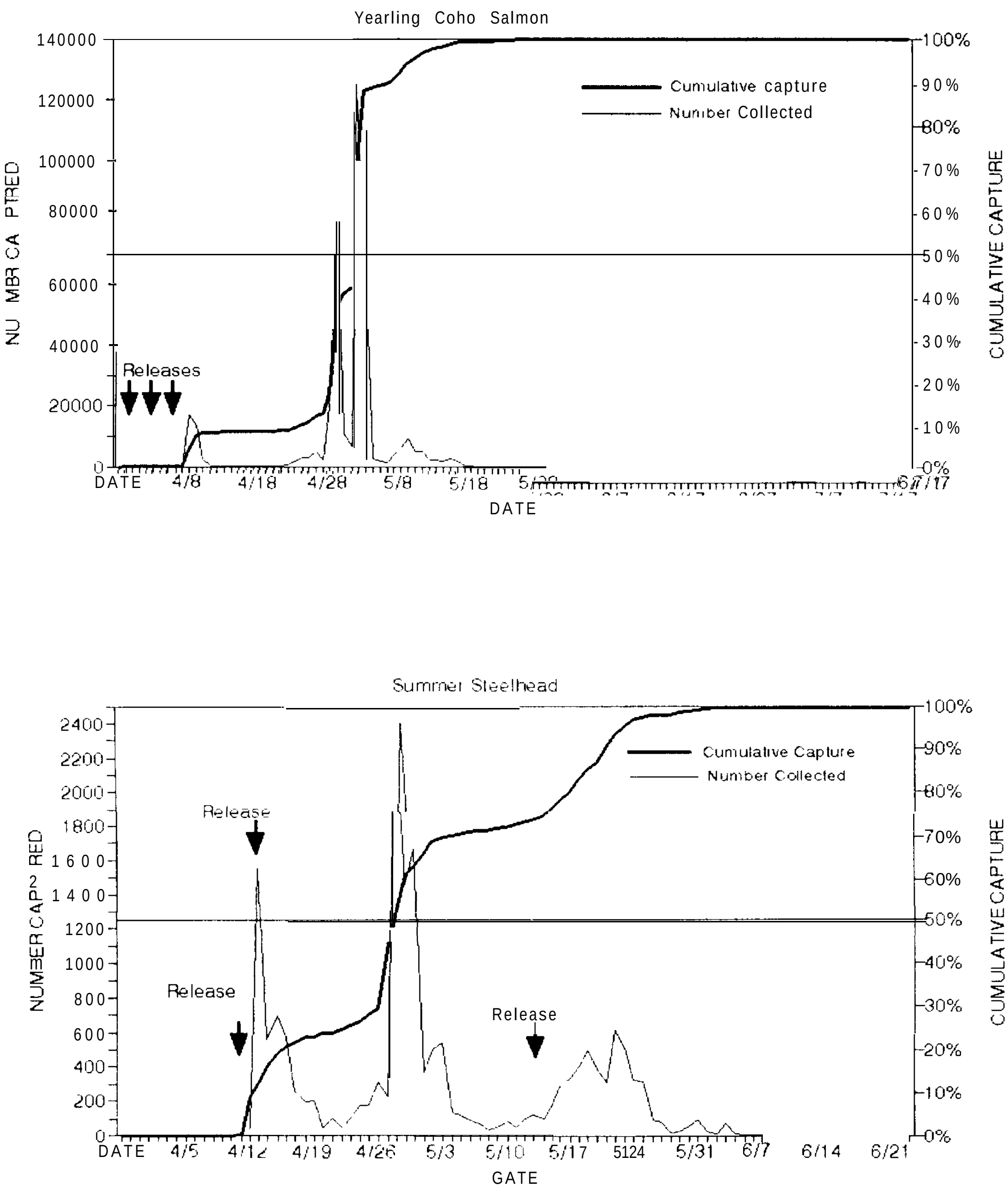
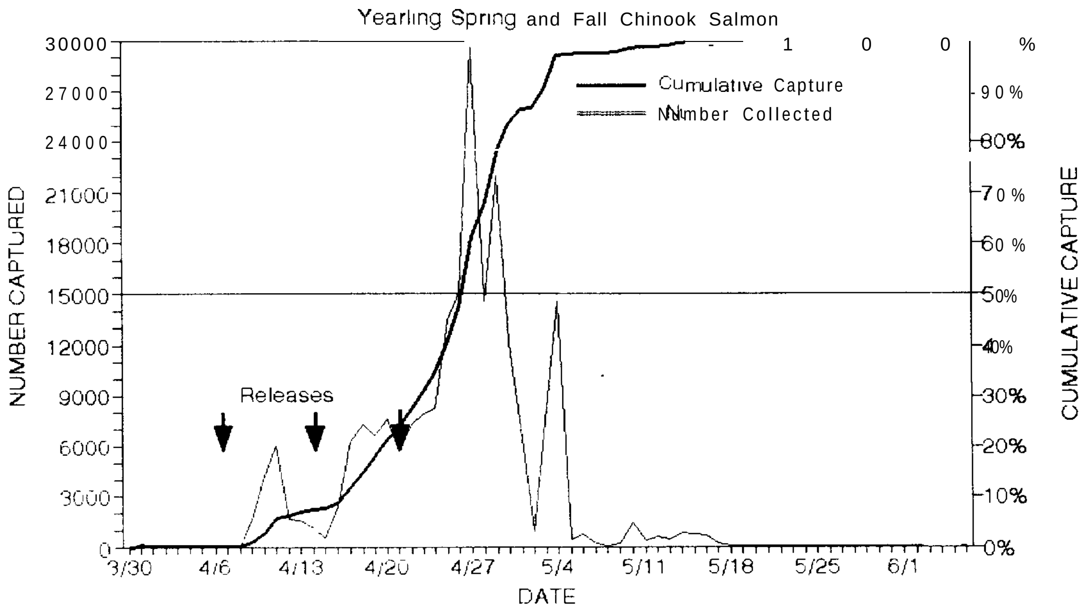


Figure 8. Migration timing, magnitude, and duration and percent cumulative capture of hatchery coho salmon and summer steelhead collected at West Extension Canal, Umatilla River, spring 1995.



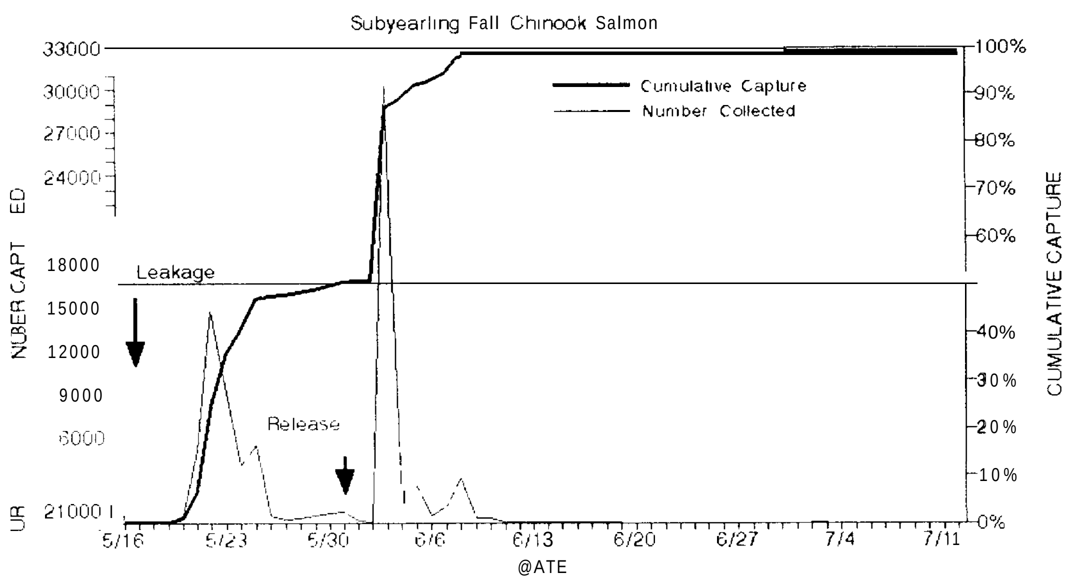
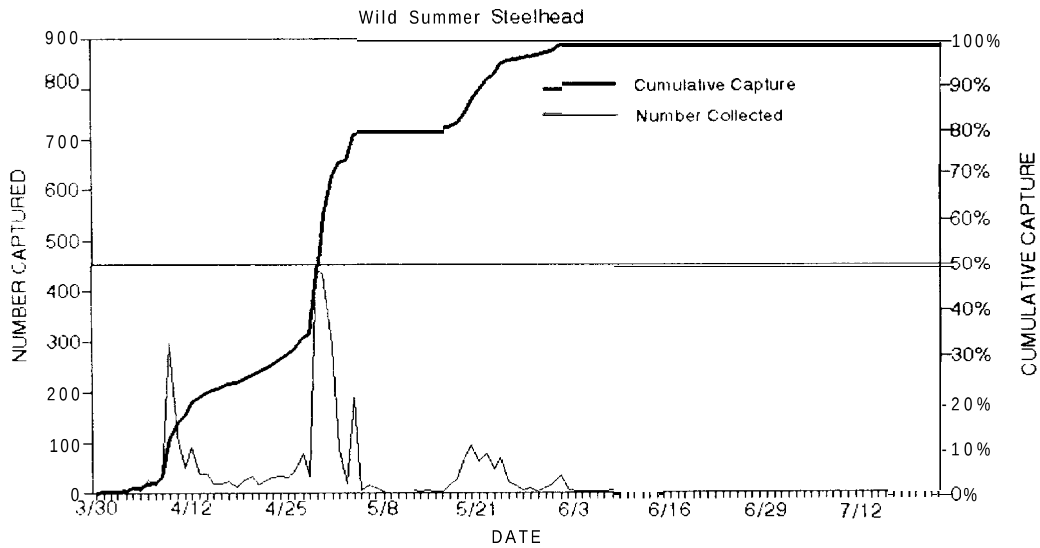


Figure 9. Migration timing, magnitude, and duration and percent cumulative capture of hatchery spring and fall chinook salmon collected at West Extension Canal, Umatilla River, spring 1995.



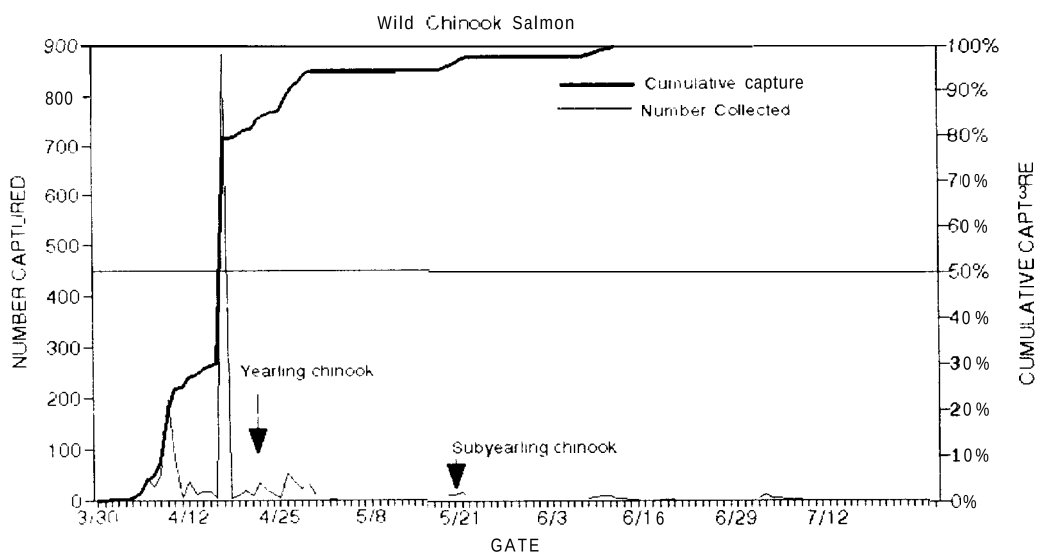


Figure 10. Migration timing, magnitude, and duration and percent cumulative capture of wild summer steelhead and chinook salmon collected at West Extension Canal, Umatilla River, spring 1995.

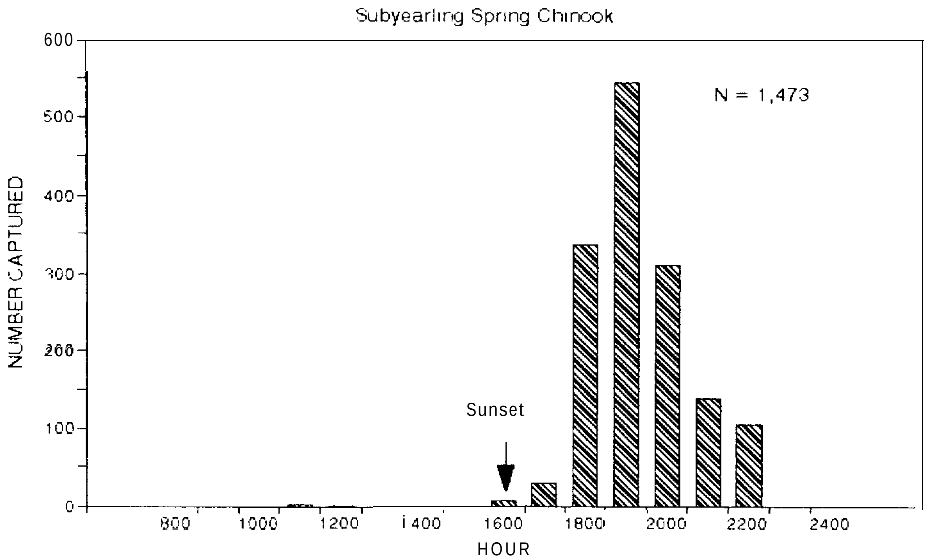
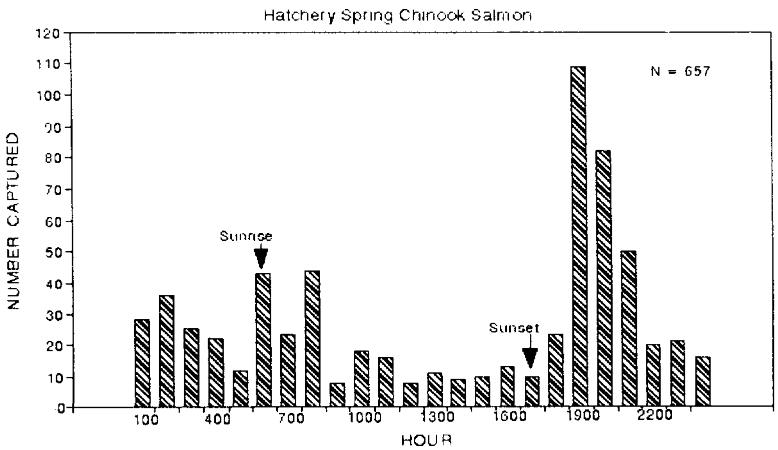
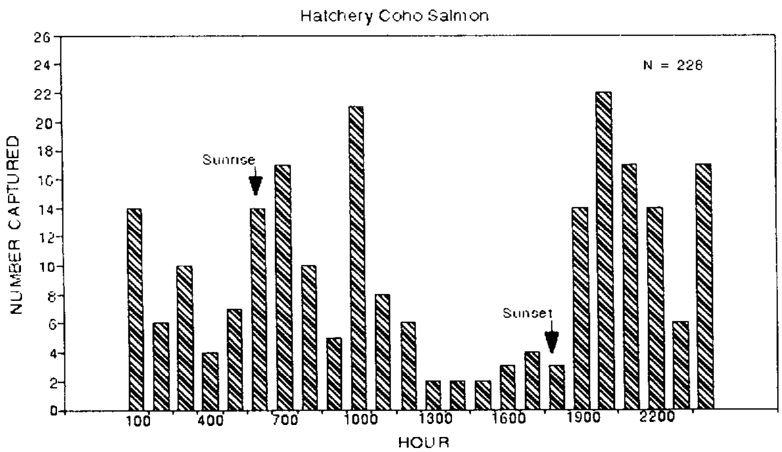


Figure 11. Diel **movement of hatchery subyearling spring chinook salmon at RM 0.5, 17 November - 13 December 1994. Hours are in military time and sunset time is indicated.**





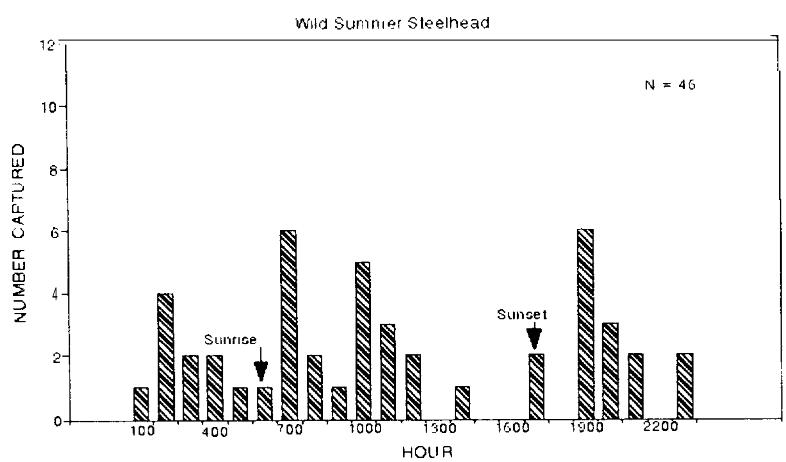
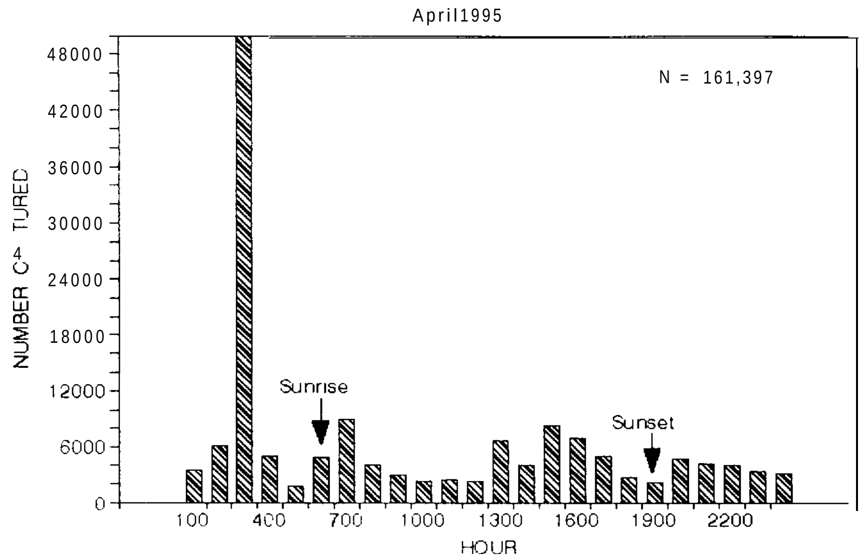


Figure 12. Diel **movement of hatchery spring chinook and** coho **salmon and wild summer steelhead at Feed Canal, Umatilla River, 20 March - 28 March** 1995. **Hours are in military time and sunrise** and **sunset times are indicated.**



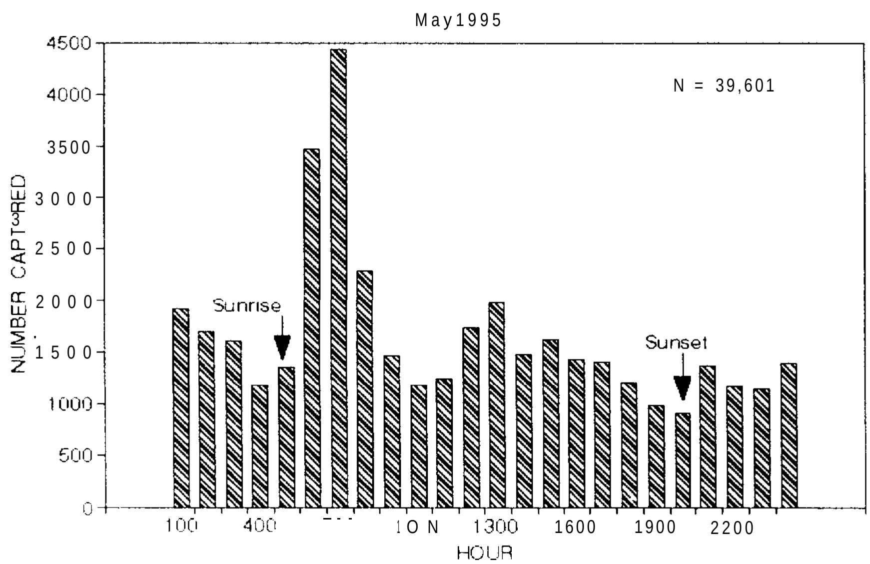


Figure 13. Diel movement of hatchery coho salmon at West Extension Canal, April and May 1995. Hours are in military time and sunrise and sunset times are indicated.

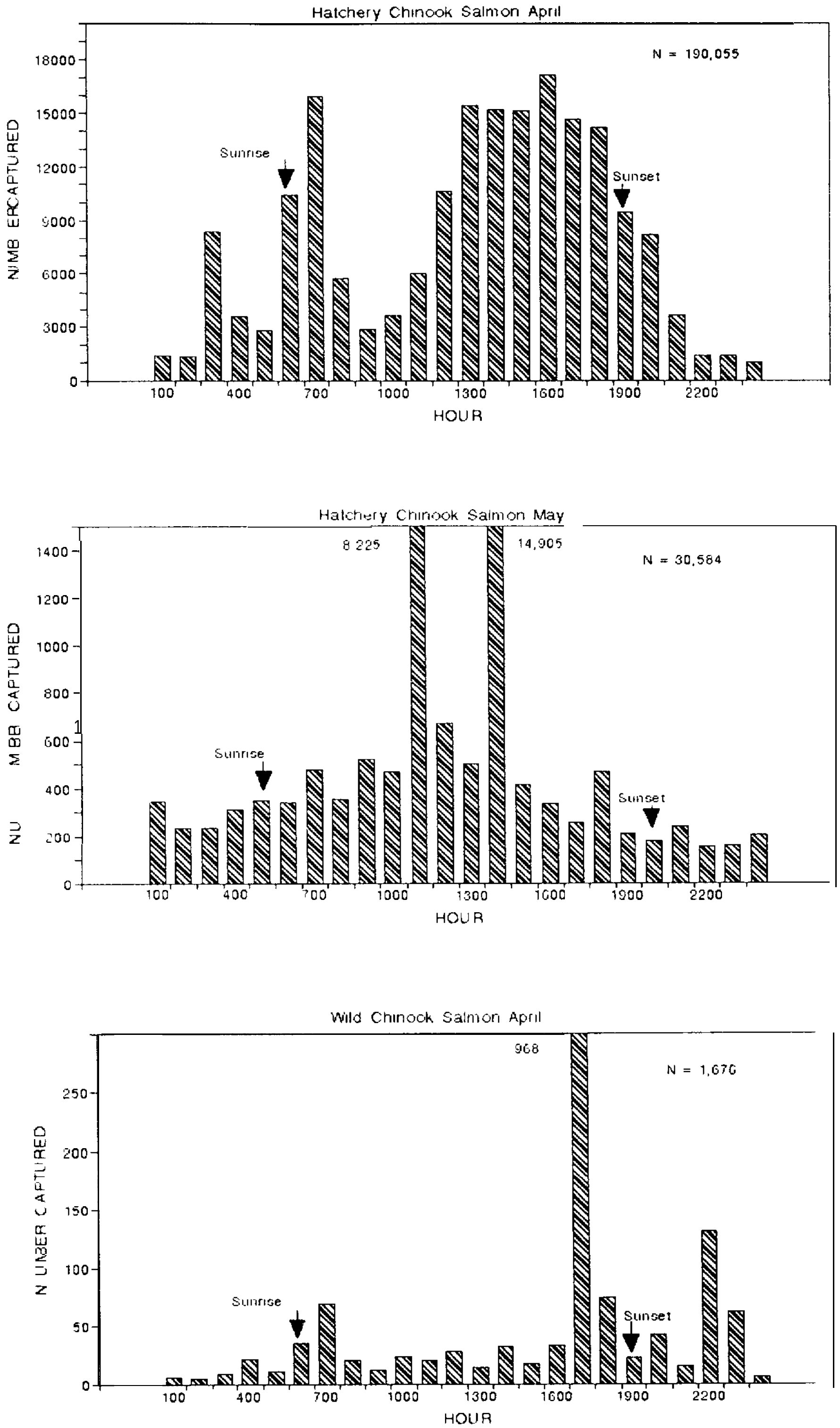


Figure 14. Diel **movement of yearling hatchery and wild chinook salmon at West Extension Canal, Umatilla River, April and May 1995. Hours are in military time and sunrise and sunset times are indicated.**

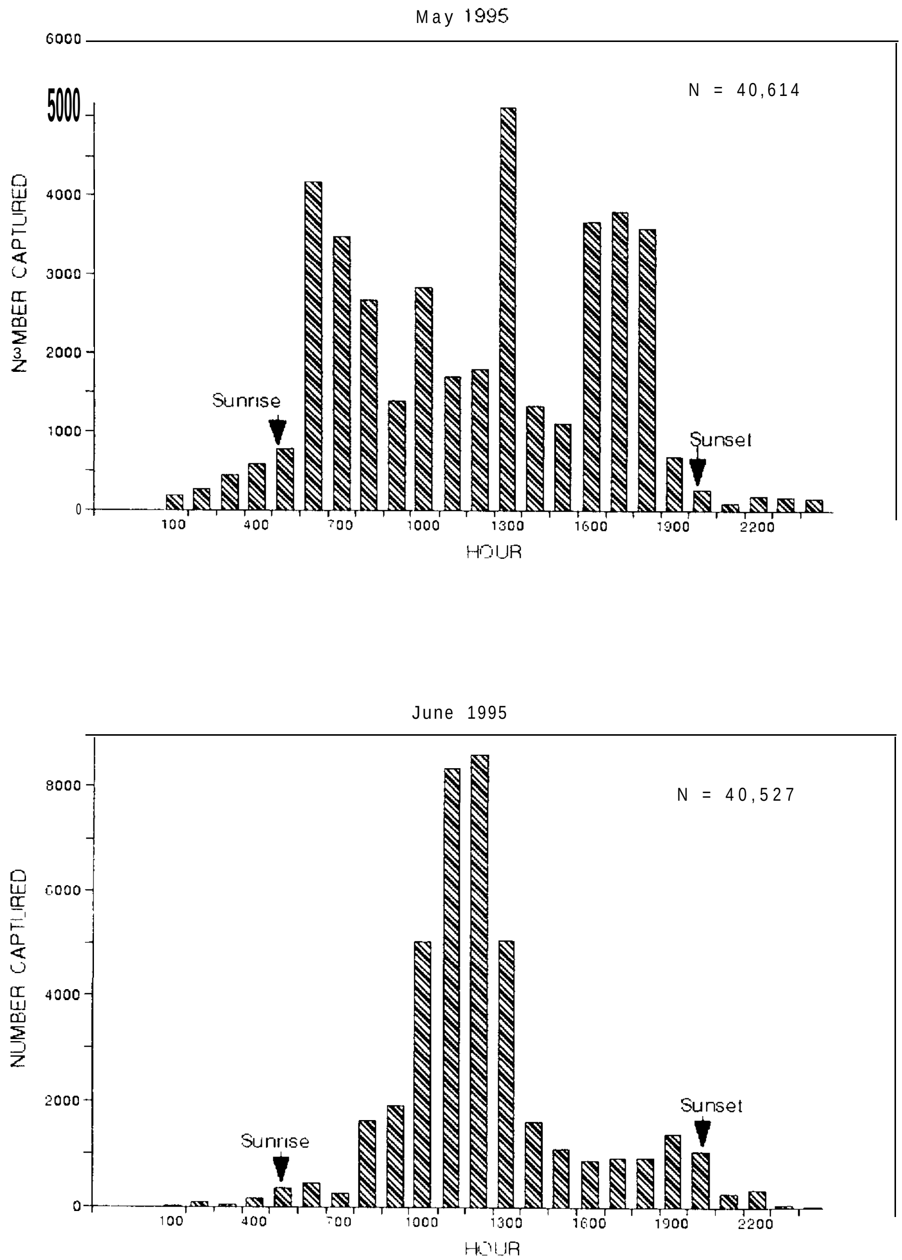


Figure 15. Diel movement of subyearling hatchery fall chinook salmon at West Extension Canal, Umatilla River, May and June 1995. Hours are in military time and sunrise and sunset times are indicated.

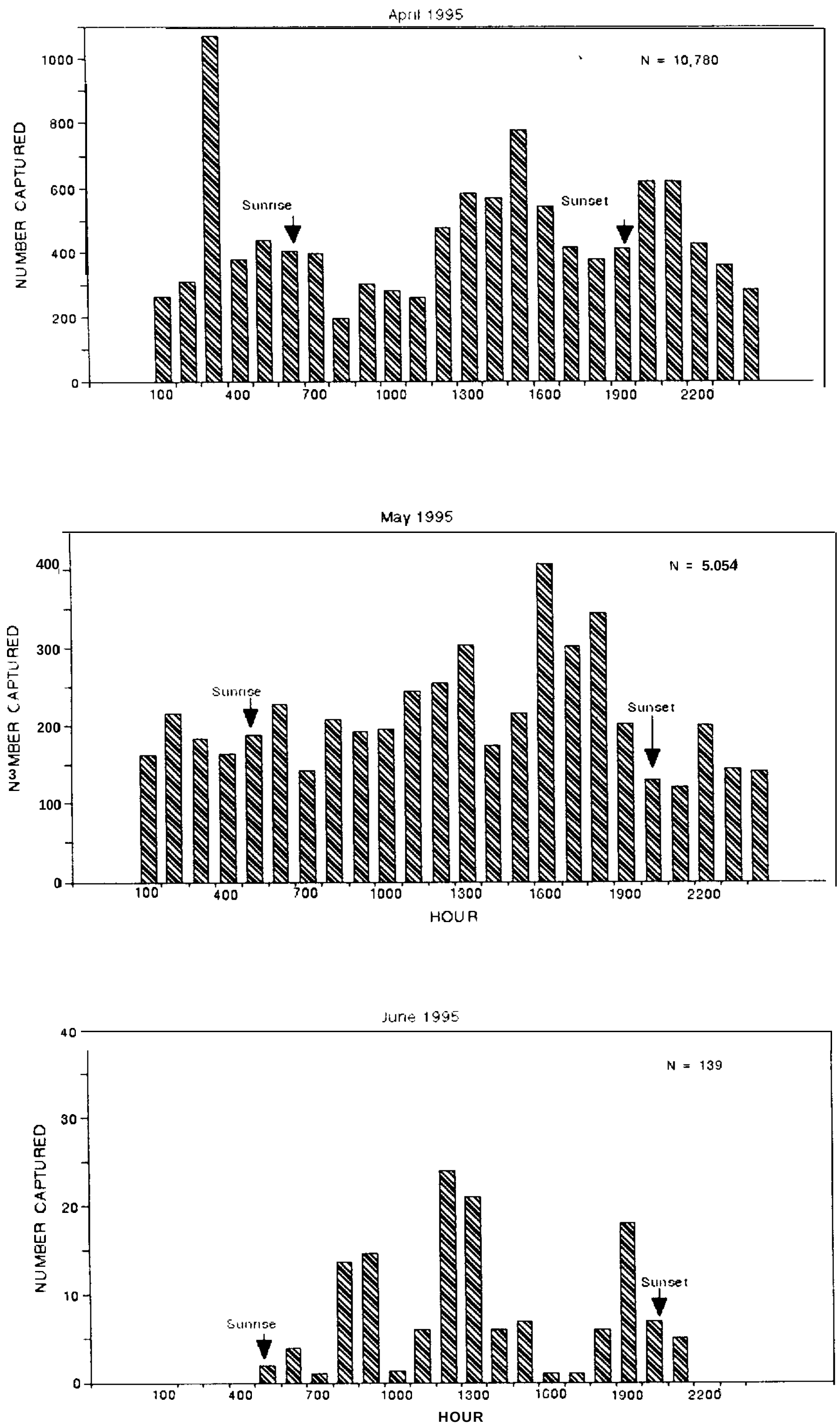


Figure 16. Diel movement of hatchery summer steelhead at West Extension Canal, Umatilla River, April - June 1995. Hours are in military time and sunrise and sunset times are indicated.

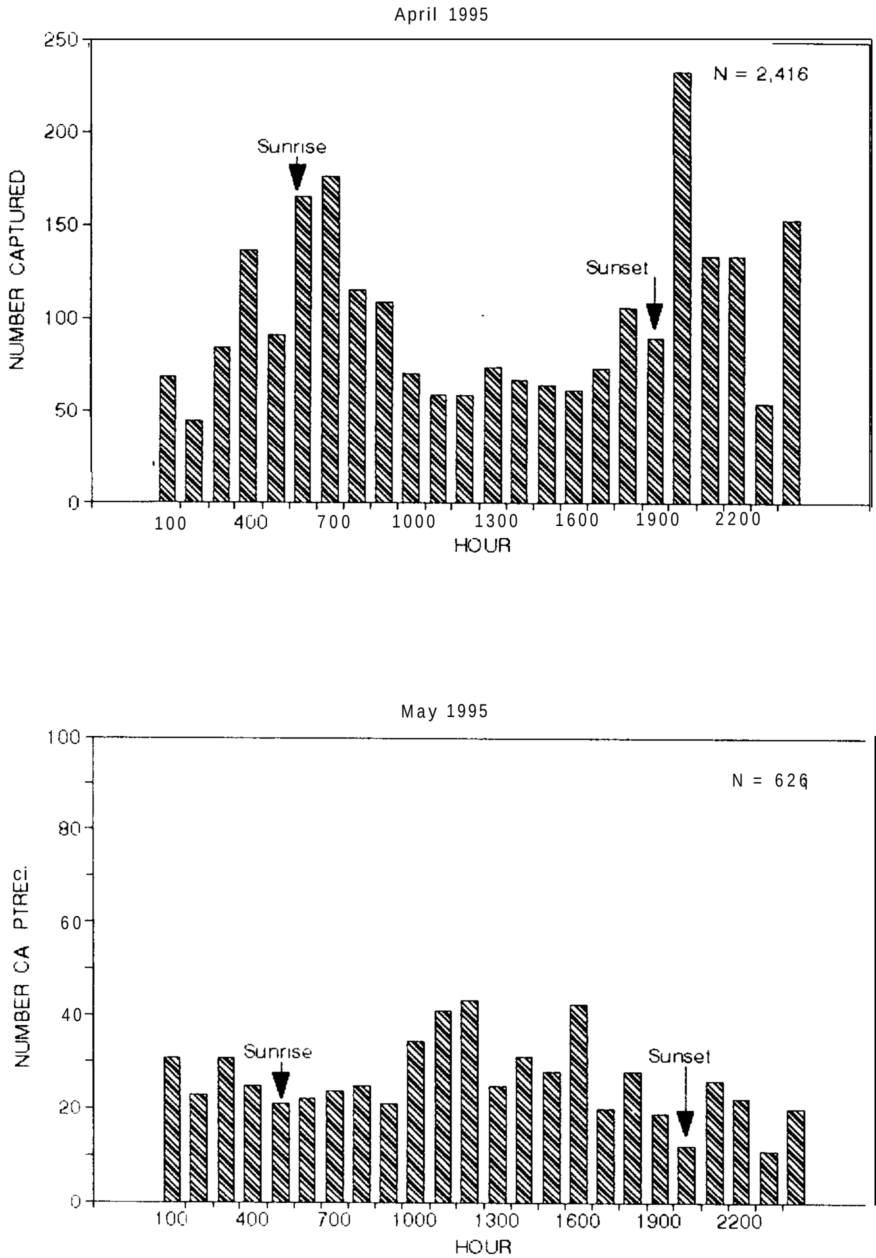


Figure 17. Diel **movement of wild summer steelhead at West Extension Canal, Umatilla River, April - May 1995. Hours are in military time and sunrise and sunset times are indicated.**

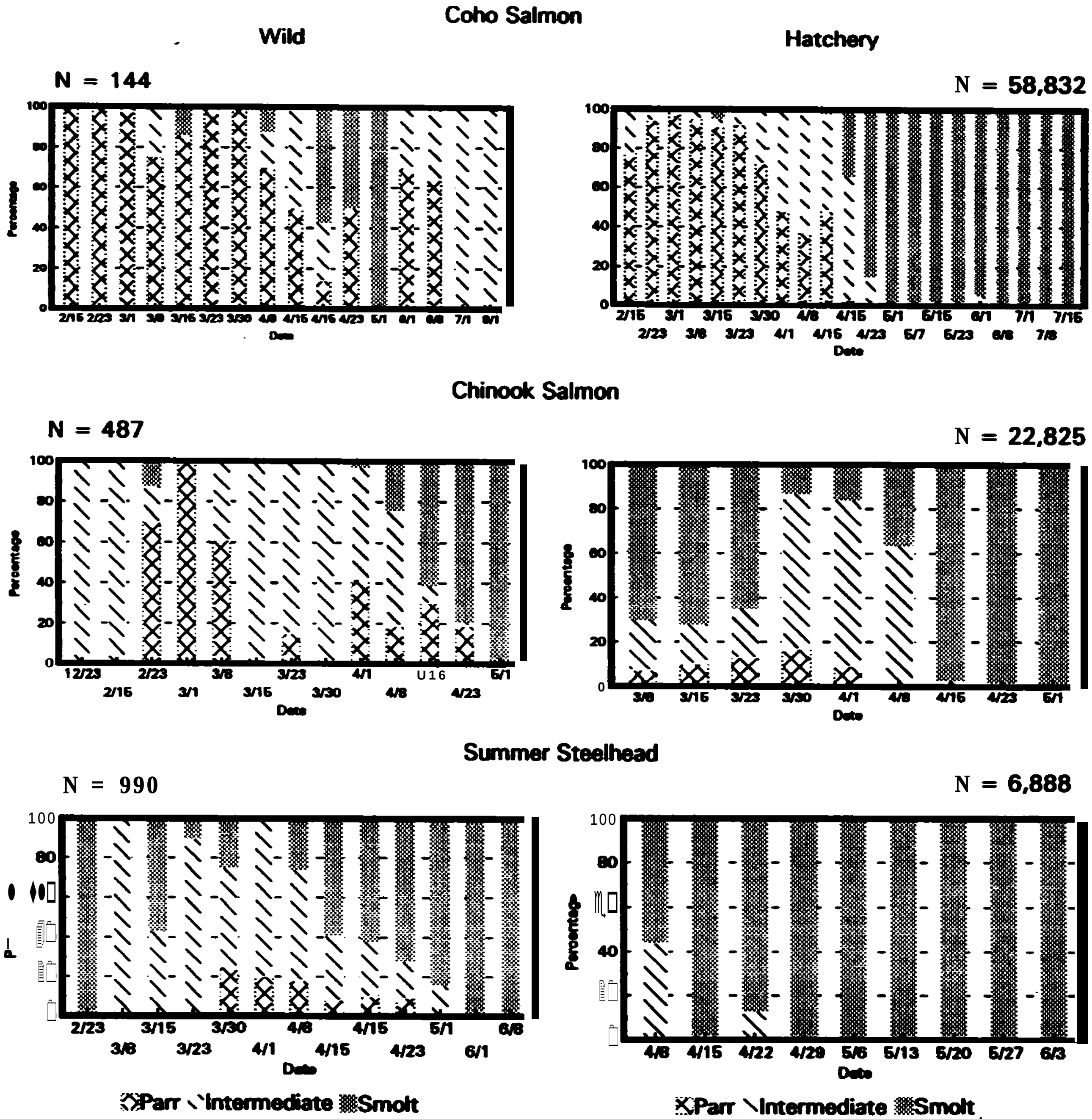
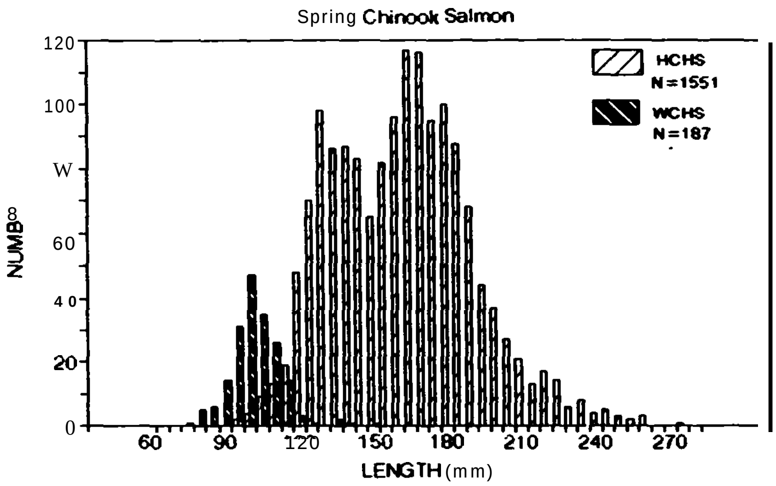
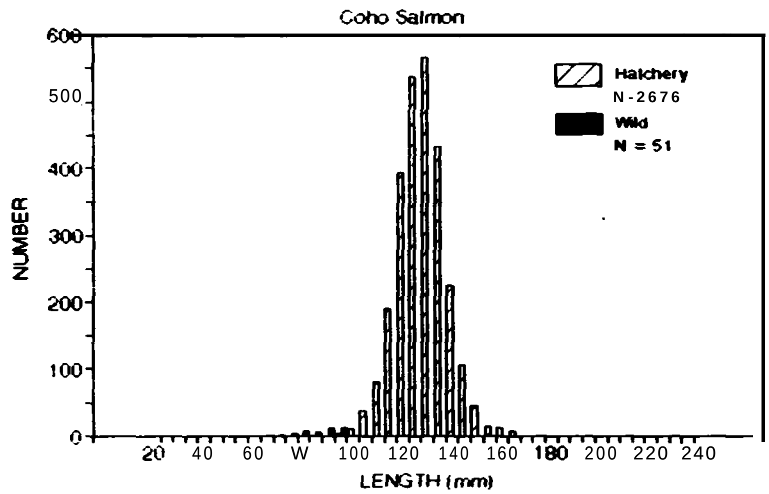


Figure 18. Smoltification index for wild and hatchery coho salmon, chinook salmon, and summer steelhead collected on the Umatilla River, December 1994 through July 1995. Dates indicate a week of collection.





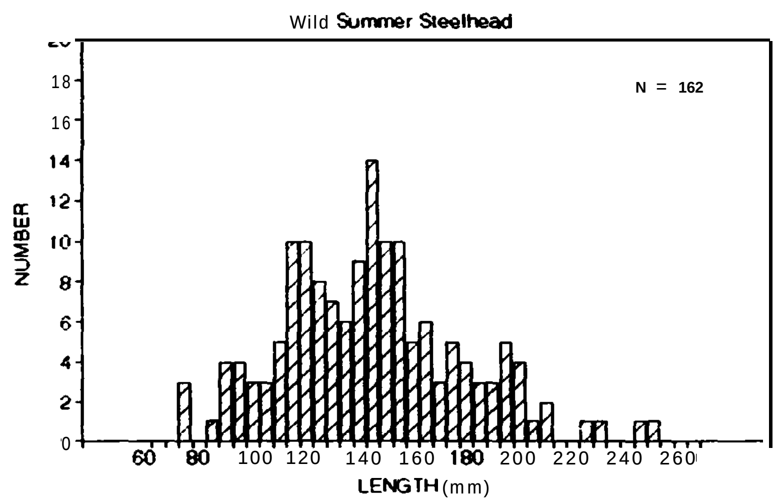


Figure 19. Length-frequency distributions for hatchery and wild spring chinook and coho salmon and wild summer steelhead collected at Feed Canal, Umatilla River, March 1995. Distributions are in 5-mm increments.

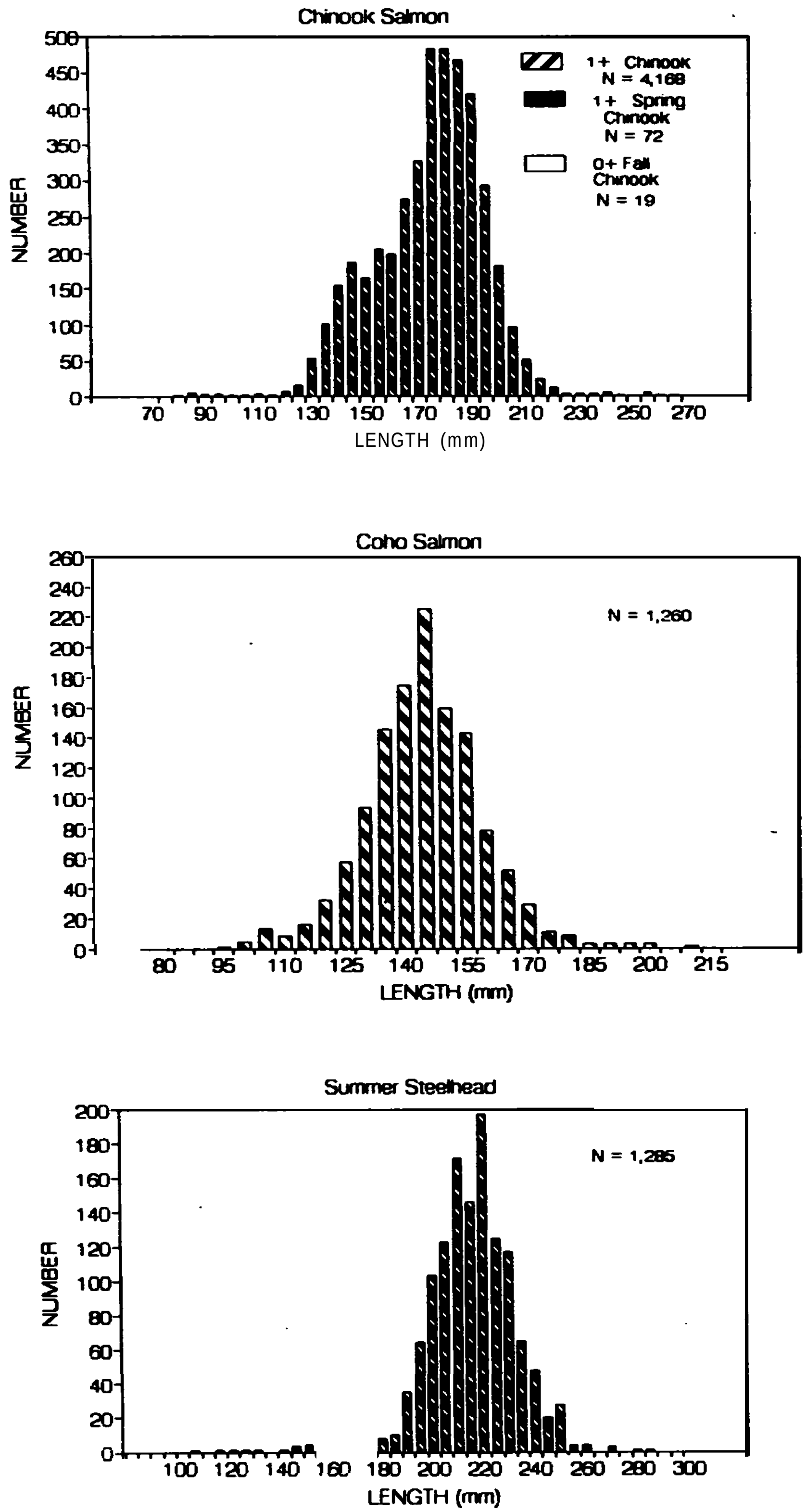


Figure 20. Length-frequency distributions for hatchery chinook salmon, coho salmon, and summer steelhead collected at West Extension Canal, Umatilla River, April - August 1995. Distributions are in 5-mm increments.

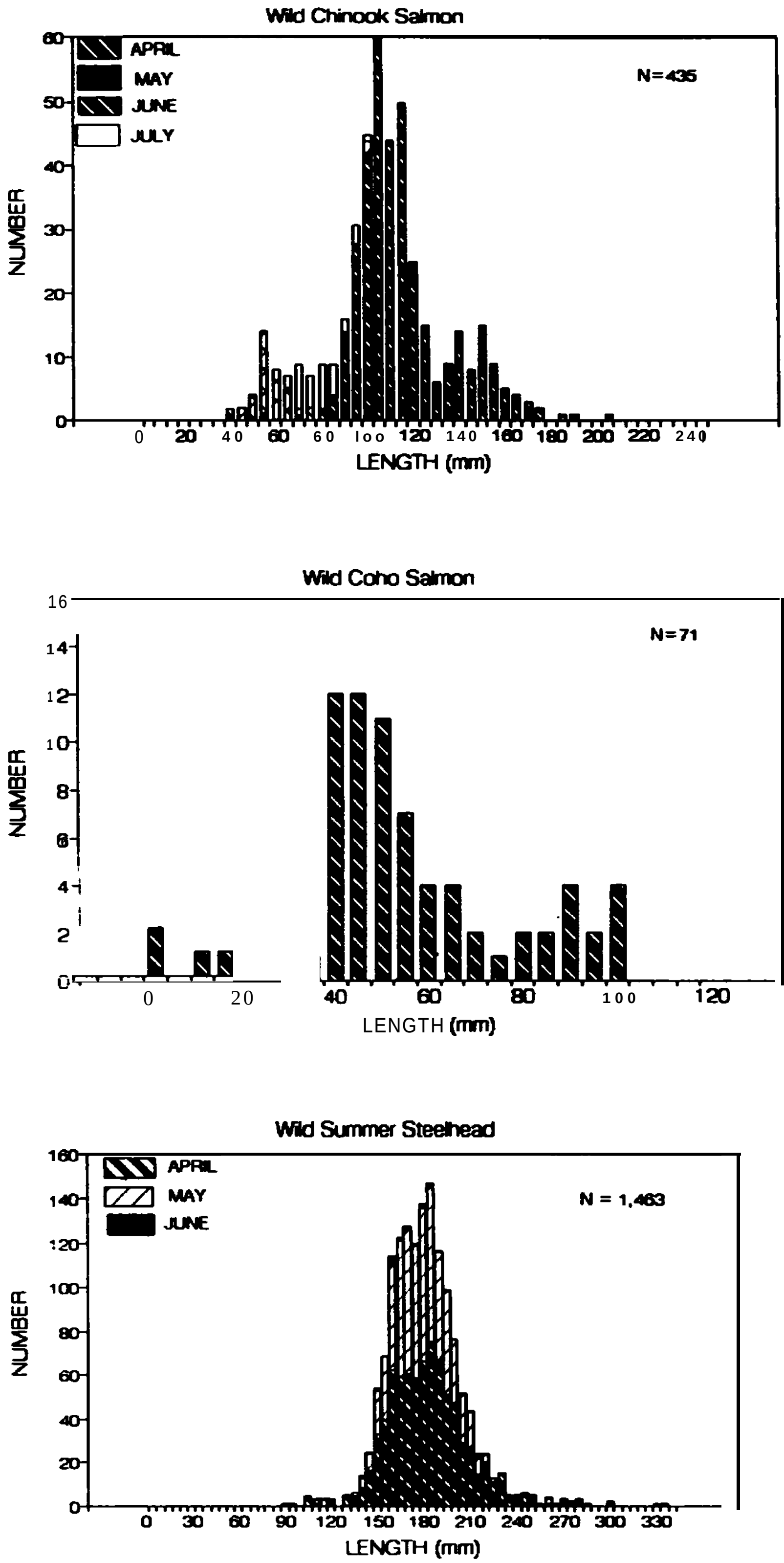


Figure 21. Length-frequency distributions for wild chinook salmon, coho 'salmon, and summer steelhead collected at West Extension Canal, Umatilla River, April - August 1995. Distributions are in 5-mm increments.

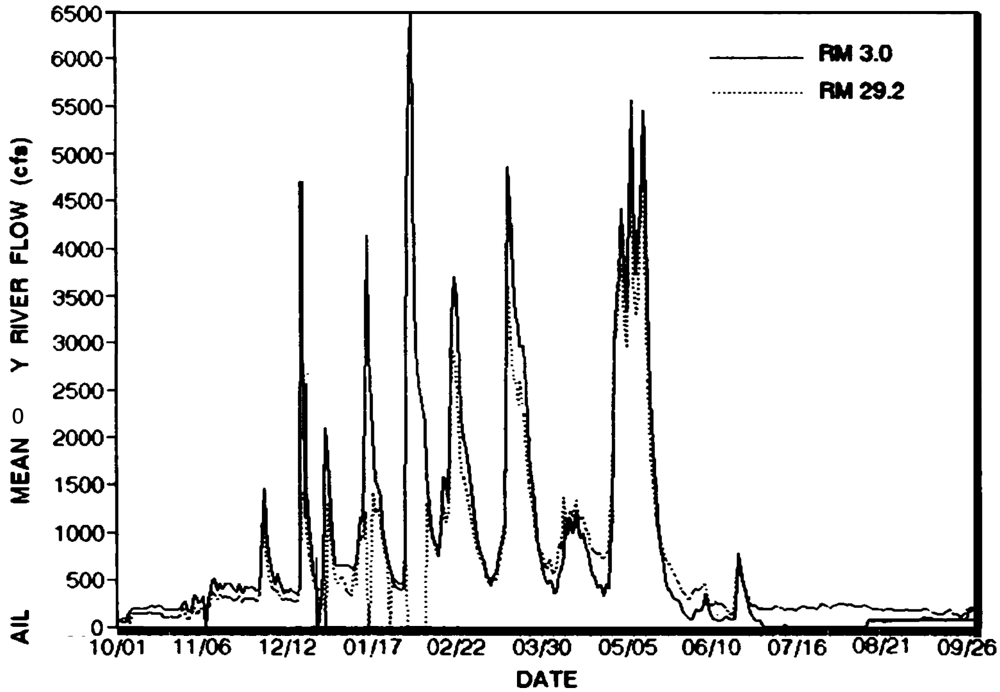


Figure 22. Mean daily river flow (cfs) at Three Mile Falls Dam (RM 3.0) and Feed Canal Dam (RM 29.2), Umatilla River, 1 October 1994 - 30 September 1995.

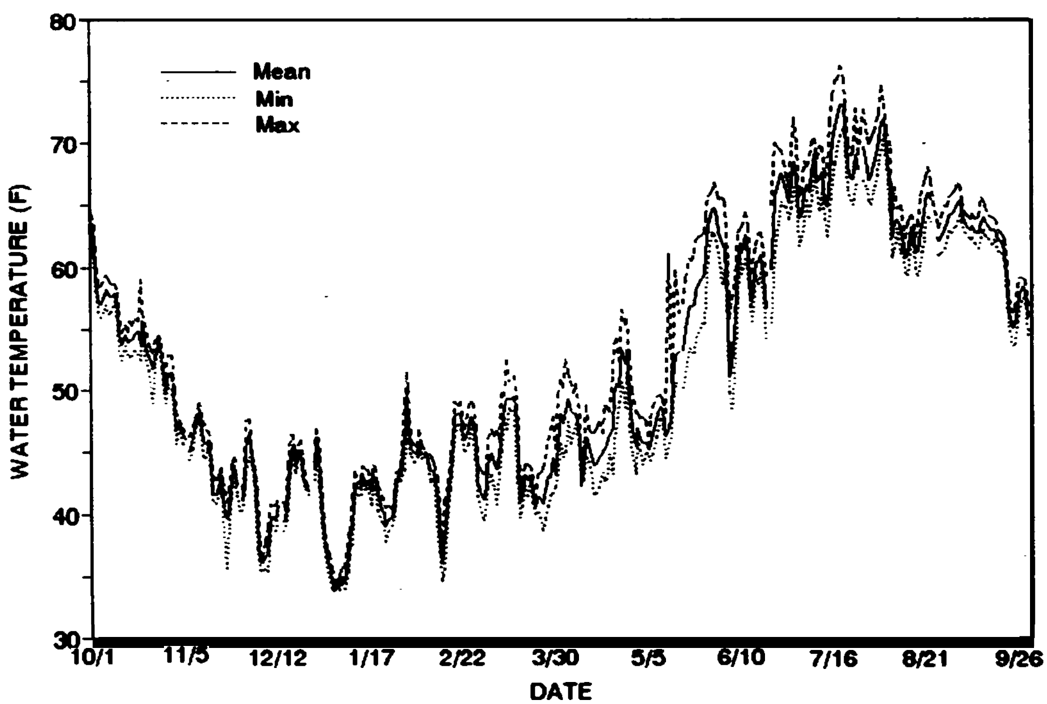


Figure 23. Mean, minimum, and maximum water temperature (°F) at the Maxwell Canal gauging station (RM 14), Umatilla River, 1 October 1994 - 30 September 1995.

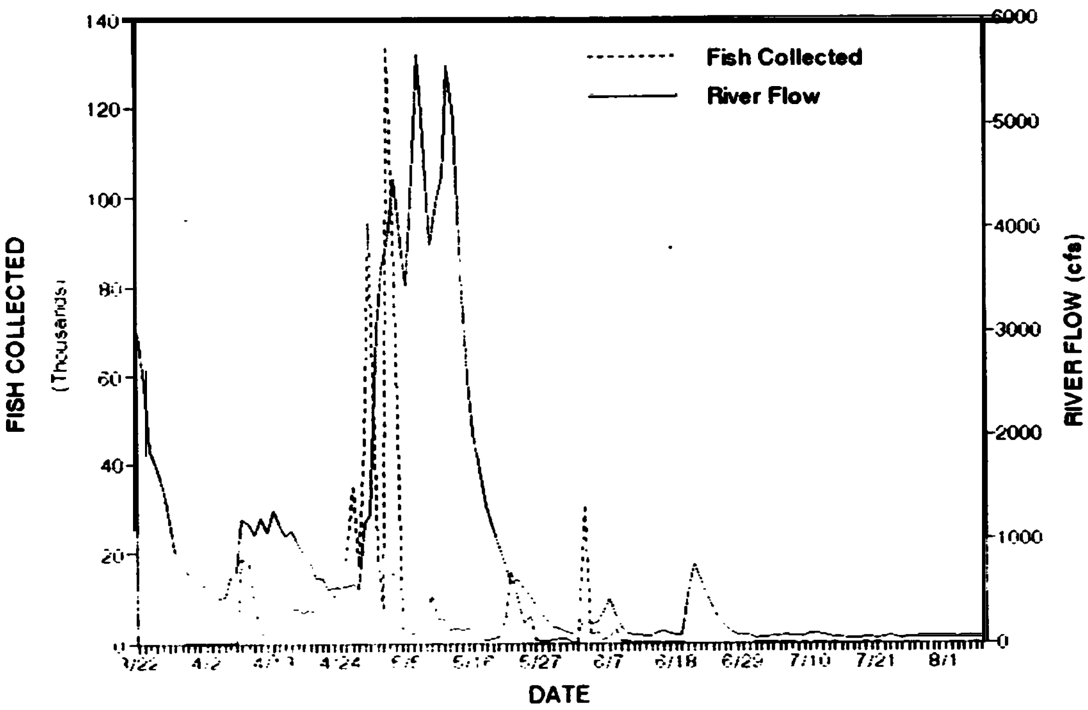


Figure 24. Total fish collected and river flow (cfs) at West Extension Canal, Umatilla River, 22 March - 7 August 1995.

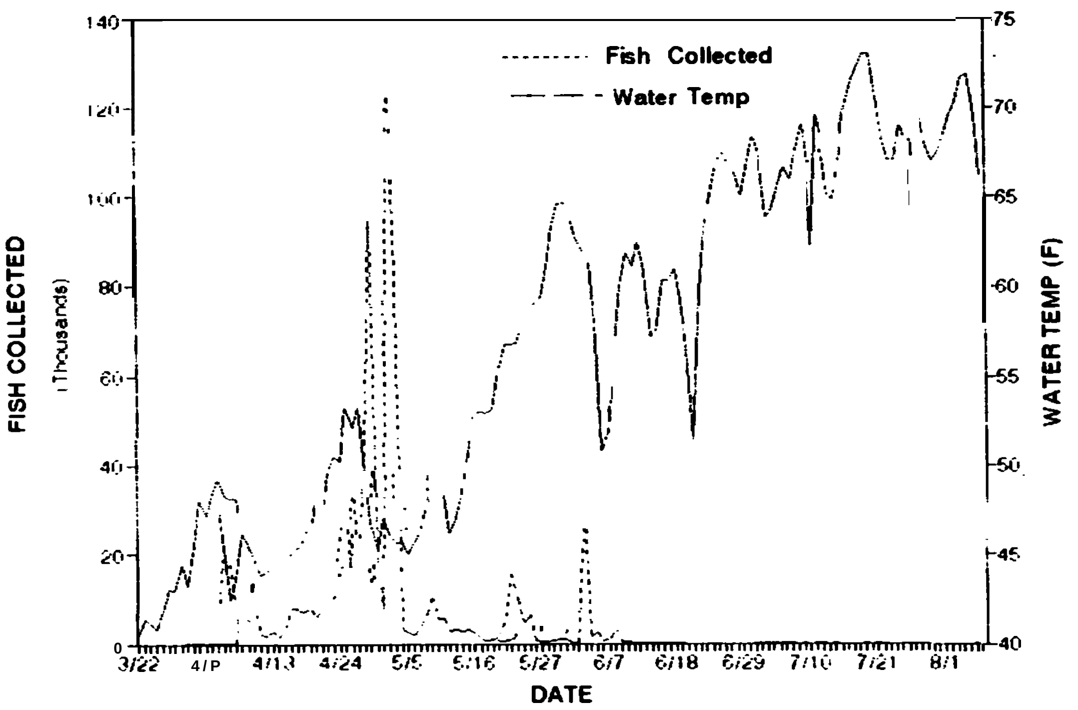


Figure 25. Total fish collected at West Extension Canal (RM 3) and water temperature (°F) at the Maxwell Canal gauging station (RM 14), Umatilla River, 22 March - 7 August 1995.

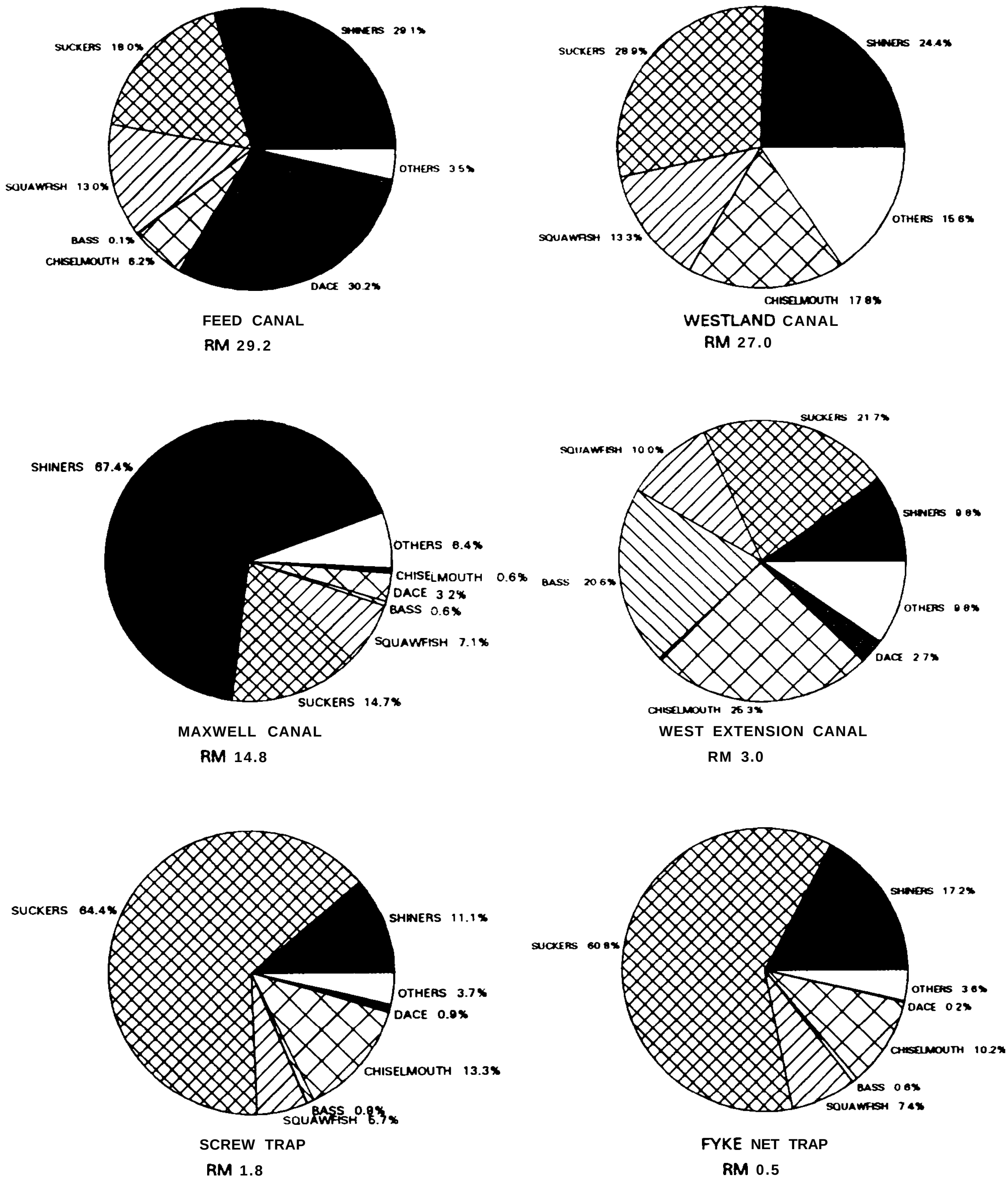


Figure 26. Species composition of resident fish collected at six sampling sites on the Umatilla River, November 1994 - September 1995.

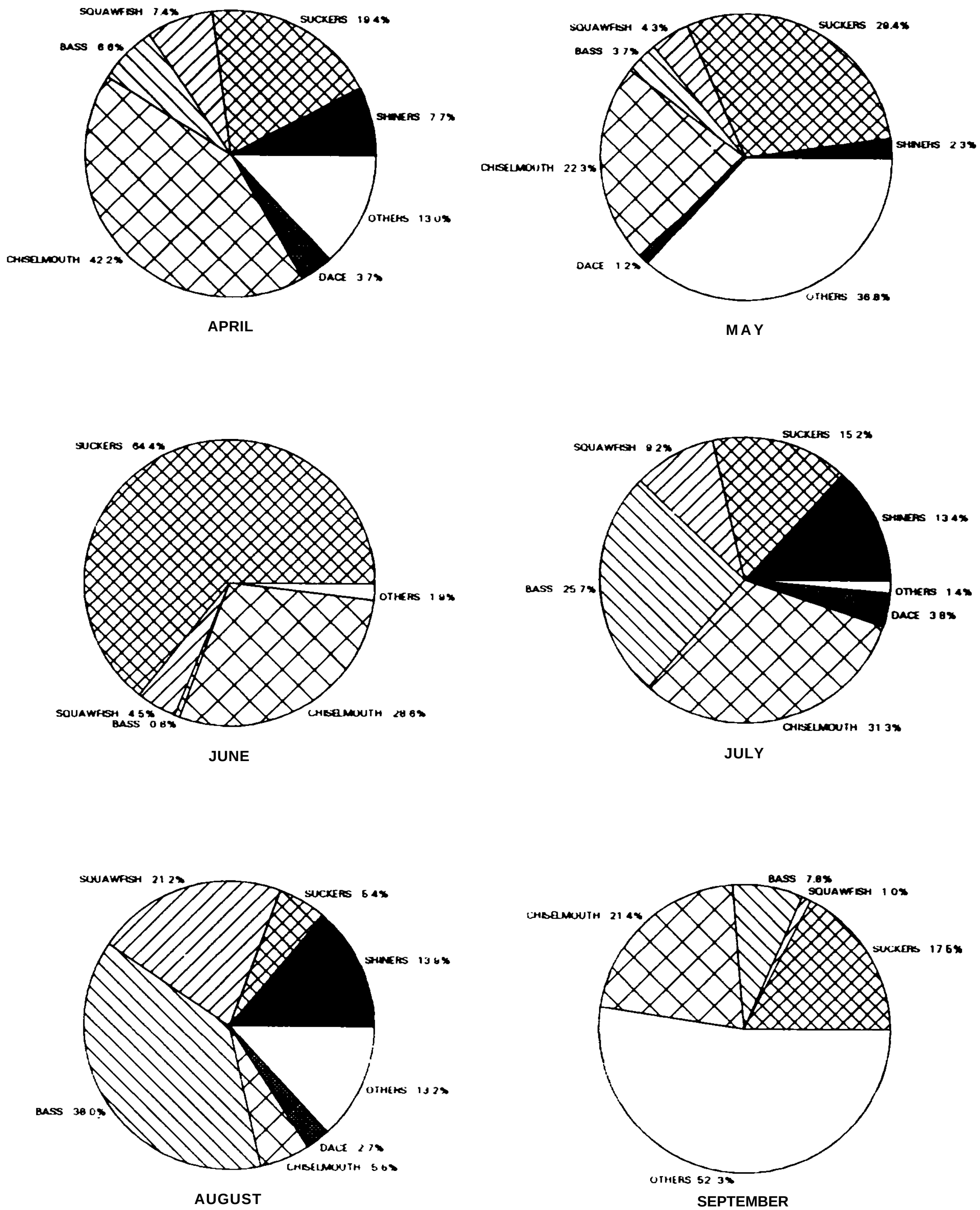


Figure 27. Monthly species composition of resident fish collected at West Extension Canal, April - September 1995.

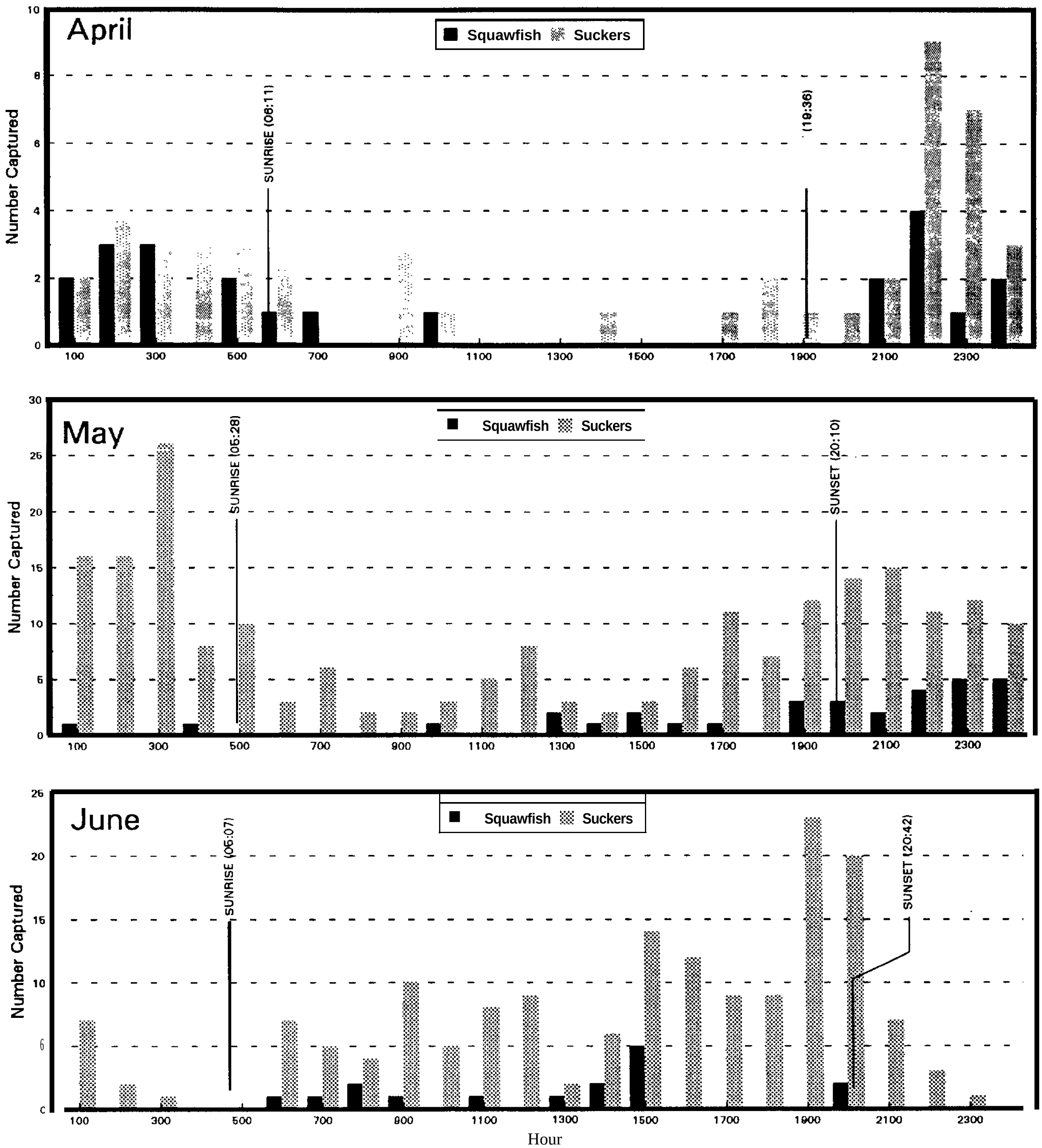


Figure 28. Diel **movement of northern squawfish and** sucher **species collected at West Extension Canal, Umatilla River, April - June 1995.**

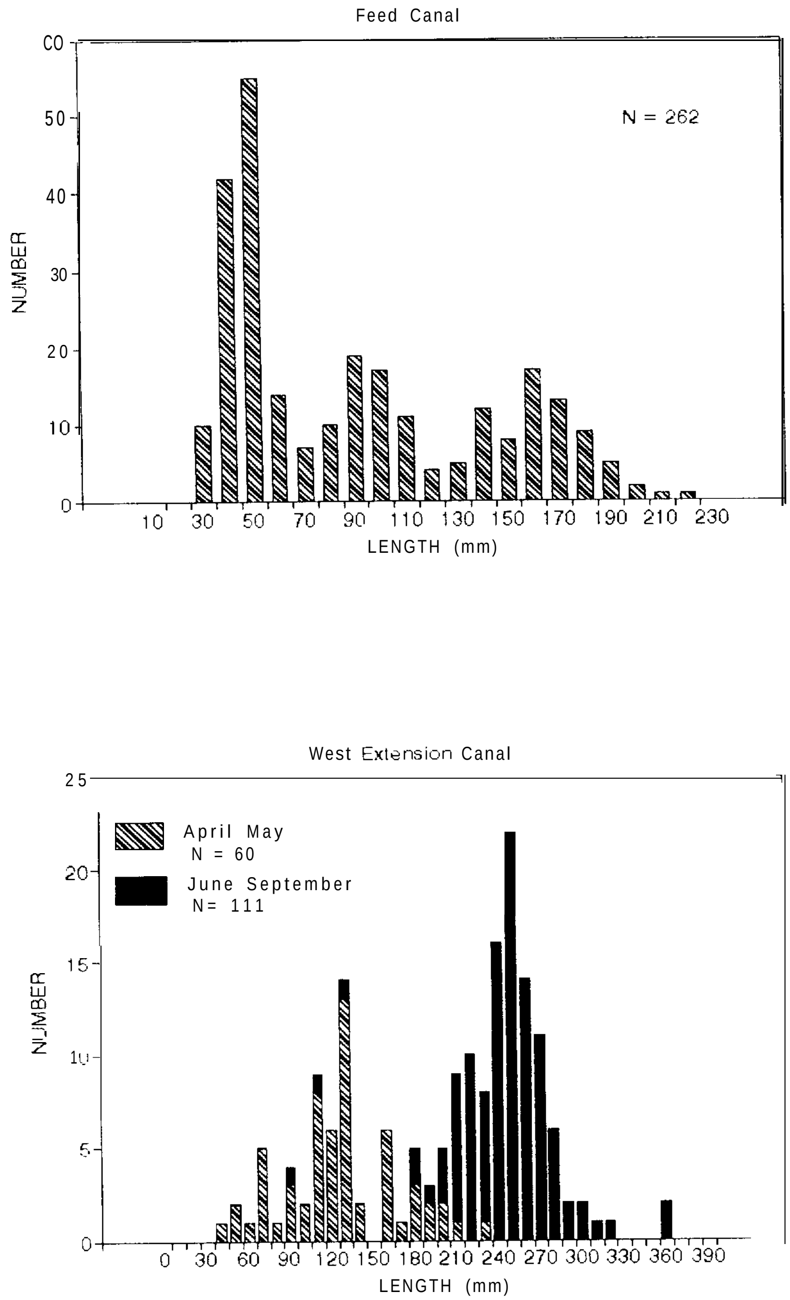


Figure 29. Length-frequency distribution of northern squawfish collected at Feed and West Extension canals, Umatilla River, March - September 1995.

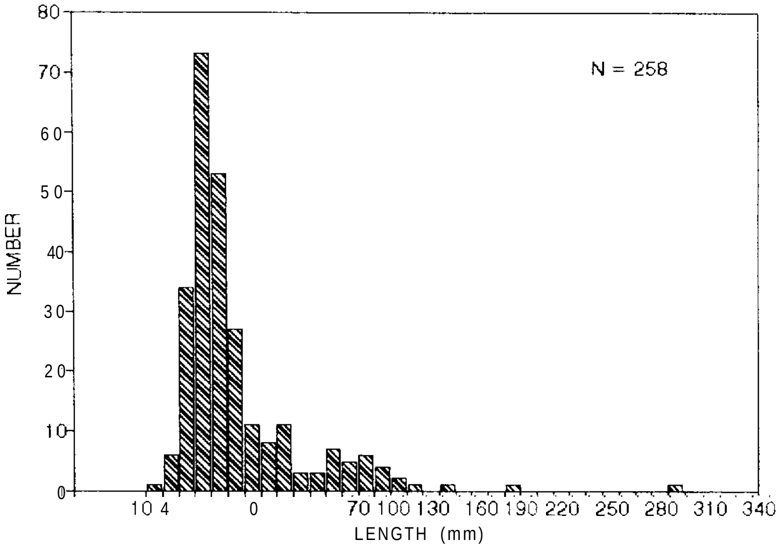


Figure 30. Length-frequency distribution of bass species collected at West Extension Canal, Umatilla River, April - September 1995.

APPENDIX A

Fish Information from Outmigration Sampling

Appendix Table A-l. Condition of juvenile salmonids collected at Feed, West Extension, Maxwell, and **Westland** canals and at lower river trap sites on the Umatilla River, December 1994 - August 1995, and results of chi-square analysis.

SITE, DATES, CHI-SQUARE	GOOD		PARTIAL		DESCALE		BIRD		BKD		INJURY		PARASITE		MORT		TOTAL
	No.	%	No	%	No	%	No.	%	No	%	No	%	NO.	%	No.	%	No
Feed Canal					Hatchery subyearling spring chinook												
12/2-2/27	229	85 8%	0	0 0%	21	7 9%	8	3 0%	0	0 0%	9	3 4%	--	--	0	0 0%	267
--																	
Feed Canal					Hatchery yearling spring chinook												
3/14-3/19	549	86 3%	46	7 2%	25	3 9%	3	0 5%	3	0 5%	10	1 6%	0	0.0%	0	0 0%	636
3/20-3/29	485	77 5%	67	10 7%	25	4 0%	16	2 6%	2	0 3%	30	4 8%	0	0 0%	1	0 2%	626
(X2 = 27 88. P < 0 001)																	
Feed Canal					Hatchery yearling coho												
2/22-2/28	1053	98.1%	0	0 0%	4	0 4%	10	0 9%	0	0.0%	6	0 6%	0	00%	0	0.0%	1073
3/1-3/7	966	94.7%	30	2 9%	4	0 4%	7	0.7%	0	0.0%	13	1 3%	0	00%	0	0 0%	1020
3/8-3/14	107	89.2%	2	1 7%	1	0 8%	2	1 7%	0	0.0%	8	6.7%	0	00%	0	0.0%	120
3/15-3/21	275	93.5%	5	1 7%	5	1 7%	3	1 0%	2	0 7%	4	1 4%	0	0 0%	0	0 0%	294
3/22-3/29	142	89.3%	6	3 8%	1	0 6%	2	1 3%	0	0 0%	8	5 0%	0	0 0%	0	0 0%	159
(X2 = 70 16 0 25 >P< 0.50)																	
Feed Canal					Wild summer steelhead												
12/5/95	4	57.1%	0	0 0%	1	14 3%	0	0 0%	0	00%	1	14.3%	1	14.3%	0	0.0%	7
12121-l2/27	4	66 7%	0	0 0%	0	0 0%	0	0 0%	0	00%	1	16 7%	1	16.7%	0	0.0%	6
1/19/96	1	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1
2/17-2/21	10	100 0%	0	0 0%	0	0 0%	0	0 0%	0	00%	0	0 0%	0	0 0%	0	0.0%	10
2/22-2/28	32	100.0%	0	0 0%	0	0.0%	0	0 0%	0	00%	0	0.0%	0	0 0%	0	0.0%	32
3/1-3/7	10	loo 0%	0	0 0%	0	0.0%	0	0 0%	0	00%	0	0.0%	0	0.0%	0	0 0%	10
3/8-3/14	3	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0.0%	0	0.0%	3

Appendix Table A-I Continued.

SITE, DATES. CHI-SQUARE	GOOD No	%	PARTIAL No.	%	DESCALE No	%	BIRD No.	%	BKD No	%	INJURY No	%	PARASITE No	%	MORT No.	%	TOTAL No.
Wild summer steelhead (continued)																	
3/15-3/21	45	93 8%	2	4 2%	1	2 1%	0	0.0%	0	0 0%	0	0.0%	0	0 0%	0	0 0%	48
3/22-3/29	28	82 4%	3	8 8%	0	0 0%	1	2 9%	0	0 0%	0	0.0%	2	5 9%	0	0 0%	34
(X2 = 5408 025 >P< 050)																	
Feed Canal — Wild coho																	
2-22-2/28	12	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	12
3/1-3/7	34	97 1%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	2.9%	0	0 0%	0	0 0%	35
3/8-3/14	5	62 5%	1	12 5%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	2	25 0%	0	0 0%	8
3/15-3/21	5	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0 0%	0	0.0%	6
3/22-3/28	6	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	6
(X2 = 23 88. 0 25 >P< 0 50)																	
Feed Canal — Wild chinook																	
12/5	41	59 4%	0	0.0%	0	0.0%	0	00%	0	0 0%	0	0 0%	28	40 6%	0	0.0%	69
12/21-1 2129	13	65 0%	0	0 0%	0	00%	0	00%	0	0.0%	0	0.0%	7	35.0%	0	0.0%	20
2/17-2/28	12	66 7%	0	0.0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	6	33 3%	0	0 0%	18
3/1-3/7	25	75 8%	0	0 0%	0	0 0%	1	3 0%	0	0 0%	0	0 0%	7	21.2%	0	0 0%	33
3/8-3/13	14	82 4%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	3	17.6%	0	0.0%	17
3/17-3/24	12	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0.0%	0	0 0%	0	0 0%	12
3/25-3/28	12	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0 0%	12
(X2 = 21 51, 0 95 >P< 0 975)																	

Appendix Table A-l. Continued.

SITE, DATES, CHI-SQUARE	GOOD No	GOOD %	PARTIAL No	PARTIAL %	DESCALE No	DESCALE %	BIRD No	BIRD %	BKD No	BKD %	INJURY No	INJURY %	LEECH No	LEECH %	MORT No.	MORT %	TOTAL No
West Extension Canal — Hatchery yearling chinook																	
3/30-4/8	135	84 9%	11	6 9%	4	2 5%	4	2 5%	2	1 3%	2	1 3%	1	0 6%	0	0 0%	159
419-4 15	3936	93 3%	114	2 7%	66	1 6%	29	0 7%	9	0 2%	20	0 5%	46	1 1%	0	0 0%	4220
4/16-422	5148	89 8%	233	4 1%	40	0 7%	127	2 2%	7	0 1%	153	2 7%	12	0 2%	15	0 3%	5735
4/23-4/29	8633	97 1%	68	0 8%	35	0 4%	83	0 9%	8	0 1%	57	0 6%	3	0.0%	4	0.0%	8891
4/30-5/6	3683	96 0%	75	2 0%	34	0 9%	20	0 5%	12	0 3%	6	0 2%	0	0 0%	5	0 1%	3835
5/7-5/13	1535	92 1%	37	2 2%	24	1 4%	34	2 0%	8	0 5%	15	0 9%	0	0 0%	14	0 8%	1667
5/14-5/20	1279	88 4%	31	2 1%	22	1 5%	32	2 2%	32	2 2%	46	3.2%	1	0 1%	4	0 3%	1447
5/21-5/27	23	62 2%	1	2 7%	4	10 8%	2	5 4%	2	5 4%	4	10 8%	0	0 0%	1	2 7%	37
5/28-6/3	4	50 0%	1	12 5%	0	0 0%	1	12 5%	2	25 0%	0	0 0%	0	0 0%	0	0 0%	8
(X2 = 130429, P < 0001)																	
West Extension Canal — Hatchery yearling summer steelhead																	
4/9-4/15	800	87 1%	72	7 8%	13	1 4%	24	2 6%	0	0 0%	10	1 1%	0	0 0%	0	0 0%	919
4/16-4/22	345	84 1%	43	10 5%	6	1 5%	8	2 0%	0	0 0%	3	0 7%	0	0 0%	5	1 2%	410
4/23-4/29	763	77 3%	184	18 6%	29	2.9%	9	0 9%	0	0 0%	1	0 1%	0	0 0%	1	0 1%	987
4/30-5/6	320	40 9%	296	37 8%	135	17 2%	25	3 2%	0	0 0%	1	0 1%	0	0.0%	6	0 8%	783
5/7-5/13	223	59 8%	96	25 7%	40	10 7%	9	2 4%	0	0 0%	4	1 1%	0	0 0%	1	0 3%	373
5/14-5/20	1134	53 9%	503	23 9%	248	11 8%	179	8 5%	0	0 0%	37	1 8%	0	0 0%	1	0.0%	2102
5/21-5/27	749	48 8%	344	22 4%	209	13 6%	223	14 5%	0	0 0%	5	0 3%	0	0 0%	4	0.3%	1534
5/28-6/3	157	62 3%	41	16 3%	17	6 7%	35	13 9%	0	0 0%	2	0 8%	0	0.0%	0	0 0%	252
6/4-6/10	9	50 0%	0	0 0%	6	33 3%	2	11 1%	0	0 0%	1	5 6%	0	0 0%	0	0 0%	18
(X2 = 108957. P < 0001)																	

Appendix Table A-1. Continued.

SITE, DATES, CHI-SQUARE	GOOD No	GOOD %	PARTIAL No	PARTIAL %	DESCALE No	DESCALE %	BIRD No	BIRD %	BKD No	BKD %	INJURY No	INJURY %	LEECH No	LEECH %	MORT No.	MORT %	TOTAL No
West Extension Canal — Hatchery subyearling fall chinook																	
5/19-5/27	19608	97 2%	68	0 3%	229	1 1%	8	0 0%	0	0 0%	135	0.7%	0	0 0%	125	0.6%	20173
5/28-6/3	7175	99 3%	13	0 2%	2	0 0%	16	0.2%	0	0 0%	19	0 3%	0	0 0%	3	0.0%	7228
6/4-6/10	8555	96 4%	175	2 0%	54	0 6%	59	0 7%	0	0 0%	28	0 3%	0	0 0%	1	0 0%	8872
6/11-6/17	198	85 7%	6	2 6%	4	1 7%	0	0 0%	0	0 0%	1	0.4%	0	0 0%	22	9 5%	231
6/18-6/24	7	87 5%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	12 5%	8
6/25-7/1	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0
7/2-7/13	1	14 3%	3	42 9%	3	42 9%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	7
(X2 = 1433 64. F < 0 001)																	
West Extension Canal — Hatchery yearling coho																	
3/30-4/8	239	89 2%	12	4 5%	3	1 1%	3	1 1%	0	0 0%	11	4 1%	0	0 0%	0	0 0%	268
4/9-4/15	1332	95 3%	13	0.9%	10	0 7%	15	1 1%	0	0 0%	24	1 7%	0	00%	4	0.3%	1398
4/16-4/22	456	93 6%	20	4.1%	3	0 6%	4	0 8%	0	0 0%	3	0 6%	0	00%	1	0 2%	487
4/23-4/29	7327	98 8%	39	0 5%	11	0 1%	31	0 4%	0	00%	6	0 1%	0	00%	3	0 0%	7417
4/30-5/6	18567	96 2%	487	2 5%	110	0 6%	101	0 5%	0	0 0%	23	0.1%	0	00%	3	0 0%	19291
5/7-5/13	19362	93 5%	626	3 0%	289	1 4%	338	1 6%	0	0 0%	62	0 3%	0	0 0%	29	0.1%	20726
5/14-5/20	6575	95 8%	73	1 1%	49	0 7%	105	1 5%	0	0 0%	53	0 8%	0	0 0%	10	0 1%	6865
5/21-5/27	1439	94 3%	27	1 8%	32	2 1%	10	0 7%	0	0 0%	8	0 5%	0	0 0%	10	0.7%	1526
5/28-6/3	122	85 9%	11	7 7%	3	2 1%	3	2 1%	0	0 0%	3	2 1%	0	00%	0	0.0%	142
6/4-6/13	5	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0 0%	0	0 0%	5
7/1-7/19	21	77 8%	2	7.4%	2	7 4%	0	0 0%	0	00%	2	7.4%	0	0 0%	0	0.0%	27
(X2 = 111062, P < 0001)																	

Appendix Table A-l. Continued.

SITE, DATES, CHI-SQUARE	GOOD No	GOOD %	PARTIAL No	PARTIAL %	DESCALE No	DESCALE %	BIRD No.	BIRD %	BKD No	BKD %	INJURY No.	INJURY %	PARASITE No.	PARASITE %	MORT No	MORT %	TOTAL No.
West Extension Canal					Wild summer steelhead												
3/30-4/8	99	85 3%	5	4 3%	4	3 4%	2	1 7%	0	0 0%	2	1 7%	2	1 7%	2	1.7%	116
4/9-415	145	91 8%	2	1 3%	0	0 0%	3	1 9%	0	0 0%	5	3 2%	2	1 3%	1	0 6%	158
4/16-422	113	89 0%	1	0 8%	0	0 0%	3	2 4%	0	0 0%	2	1 6%	8	6.3%	0	0 0%	127
4/23-4/29	262	91 9%	14	4 9%	2	0 7%	0	0 0%	0	0 0%	1	0 4%	5	1 8%	1	0 4%	285
4/30-5/6	126	86 3%	9	6 2%	1	0 7%	3	2 1%	0	0 0%	1	0 7%	6	4 1%	0	0 0%	146
5/7-5/13	9	75 0%	2	167%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	8 3%	0	0 0%	12
5/14-5/20	231	83 1%	12	4 3%	2	0 7%	10	3 6%	0	0 0%	1	0 4%	21	7 6%	1	0 4%	278
5/21-5/27	115	82 136	8	5 7%	3	2 1%	3	2 1%	0	0 0%	4	2 9%	6	4 3%	1	0.7%	140
5/28-6/3	74	88 1%	5	6 0%	0	0 0%	3	3 6%	0	0 0%	0	0 0%	1	1 2%	1	1.2%	84
6/4-6/10	8	80 0%	0	0 0%	0	0 0%	2	20 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	10
(X2 = 9969, P < 0001)																	
West Extension Canal					Wild yearling chinook												
3/30-4/8	118	70 2%	4	2 4%	1	0 6%	1	0 6%	0	0 0%	4	2 4%	40	23.8%	0	0 0%	168
4/9-415	78	78 8%	0	0.0%	2	2 0%	0	0 0%	0	0 0%	6	6 1%	12	12 1%	1	1 0%	99
4/1 6-422	38	66 7%	2	3 5%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	17	29 8%	0	0 0%	57
4/23-4/29	37	84 1%	0	0 0%	1	2 3%	1	2 3%	0	0 0%	0	0 0%	5	114%	0	0 0%	44
4/30-5/6	3	1000%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	3
5/7-5/13	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	1	100 0%	0	0.0%	1
5/14-5/20	12	75 0%	1	6 3%	1	6 3%	1	6 3%	0	0 0%	1	6 3%	0	0 0%	0	0 0%	16
(X2 = 49 75, 0 05 >P< 010)																	

Appendix Table A-I. Continued.

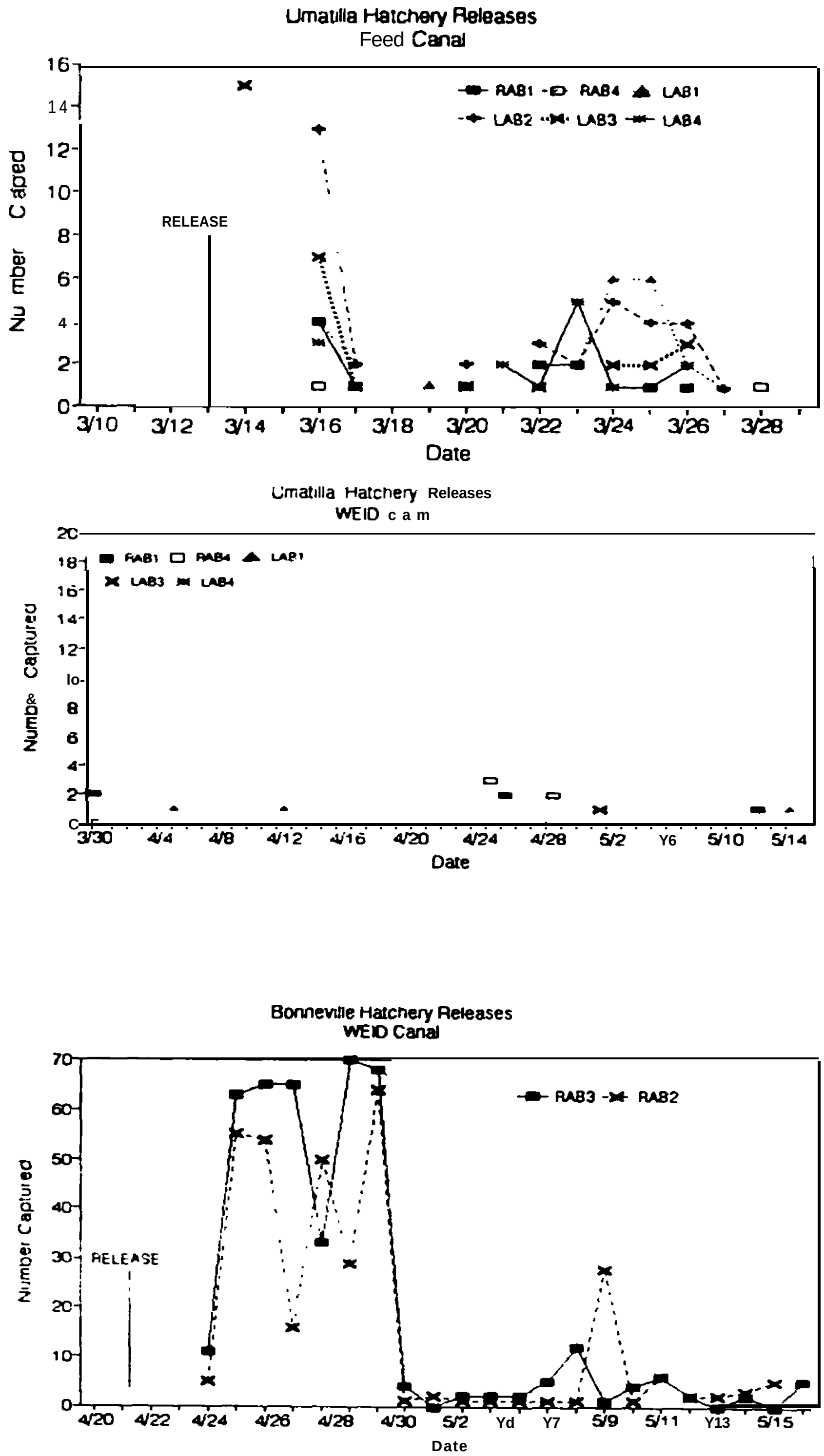
SITE, DATES, WI-SQUARE	GOOD No	GOOD %	PARTIAL No	PARTIAL %	DESCALE No	DESCALE %	BIRD No	BIRD %	BKD No	BKD %	INJURY No	INJURY %	PARASITE No	PARASITE %	MORT No.	MORT %	TOTAL No
West Extension Canal							**Wild subyearling chinook**										
4/7-4/22	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	100 0%	0	0.0%	1
4/23-4/29	4	80 0%	0	0 0%	0	c 0%	0	00%	0	0 0%	0	0 0%	1	20 0%	0	0 0%	5
5/18-5/21	5	83 3%	0	0 0%	1	16 7%	0	0.0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	6
6/4-6/10	3'	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	31
6/11-6/19	15	130 0%	0	0 0%	0	c 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	15
7/1-7/7	22	75 9%	2	6 9%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	5	17.2%	29
7/12-7/21	3	133 0%	0	0 0%	0	0 0%	0	0.0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	3
(X2 = 87 36. P< 0 001)																	
West Extension Canal							**Wild subyearling coho**										
4/16-4/22	3	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0.0%	0	0 0%	3
4/23-4/29	8	88 9%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	11 1%	0	0.0%	9
4/30-5/6	2	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	2
5/7-5/13	6	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0 0%	0	0.0%	6
5/14-5/20	3	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0.0%	0	0.0%	3
5/21-5/27	8	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0 0%	0	0.0%	8
5/28-6/3	17	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0.0%	17
6/4-6/10	28	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	28
6/11-6/17	1	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0 0%	0	0 0%	1
7/3-7/12	4	80 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	20.0%	0	0 0%	0	0 0%	5
816	C	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	100 0%	1
(X2 = 123 99. P < 0 001)																	

Appendix Table A-l. Contmued.

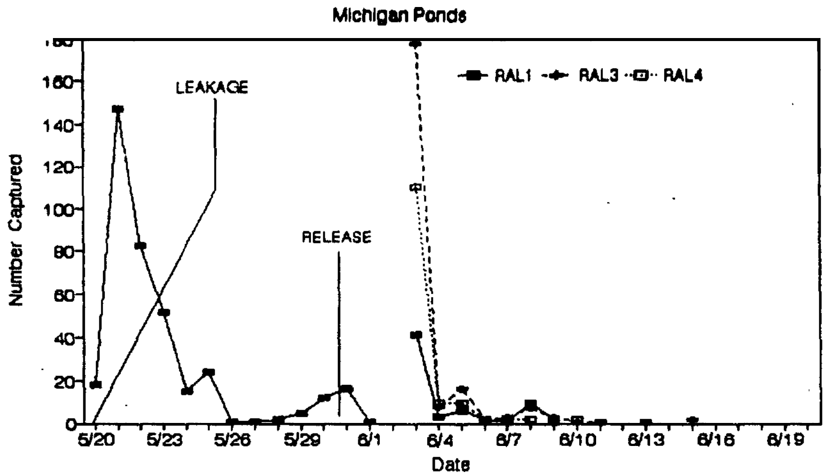
SITE. DATES, CHI-SQUARE	GOOD No	GOOD %	PARTIAL No	PARTIAL %	DESCALE No.	DESCALE %	BIRD No	BIRD %	BKD No	BKD %	INJURY No	INJURY %	PARASITE No.	PARASITE %	MORT No.	MORT %	TOTAL No.
Westland Canal				Hatchery subyearling fall chinook													
6/13-6/15	1533	81 8%	103	5.5%	31	1 7%	12	06%	0	0 0%	3	02%	0	0.0%	192	10.2%	1874
6/20-6/27	441	86 5%	41	8 0%	11	2 2%	4	0 8%	0	0 0%	2	04%	0	00%	11	2.2%	510
(X2 = 43.76 P < 0 001)																	
Westland Canal					Wild subyearling fall chinook												
6/13-6/15	128	88 9%	3	2.1%	1	07%	1	0 7%	0	0 0%	0	0 0%	0	0 0%	11	7 6%	144
6/20-6/27	179	95 7%	7	3 7%	0	0 0%	1	0 5%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	187
(X2 = 16 71. 0 005 >P<0 01)																	

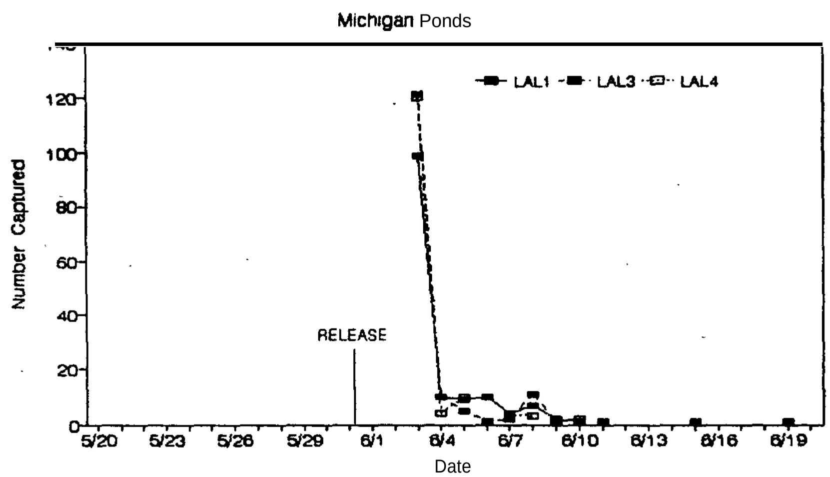
Appendix Table A-l. Continued.

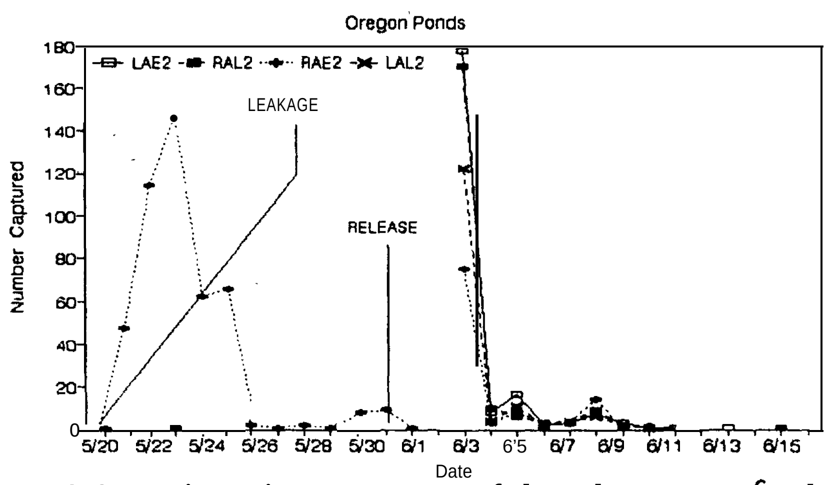
SITE, SPECIES, CHI-SQUARE	GOOD No	GOOD %	PARTIAL No	PARTIAL %	DESCALE No	DESCALE %	BIRD No.	BIRD %	BKD No	BKD %	INJURY No	INJURY %	PARASITE No	PARASITE %	MORT No	MORT %	TOTAL No
River Mile 0.5 — 17 November - 13 December 1994																	
HCHS 0+	1413	91 1%	0	0 0%	36	2 3%	87	5 6%	0	0 0%	15	1 0%	0	0 0%	0	0.0%	1551
WCH 0+	7	77 8%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	2	22 2%	0	0.0%	9
(X2=39897 P < 0 001)																	
River Mile 1.8 — 13 January'- 31 January 1995																	
HCHS 0+	148	85 1%	0	0 0%	9	5 2%	14	8 0%	0	0 0%	3	1.7%	0	0 0%	0	0.0%	174
WCH 0+	28	80 0%	0	c 0%	3	8 6%	0	0 0%	0	0 0%	0	0 0%	3	8 6%	1	2 9%	35
WSTS 1+	10	100 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	c 0%	0	0 0%	10
(X2 = 80 98. P < 0 00:)																	
Maxwell Canal — 22 June - 29 June 1995																	
HCHF 0+	580	84 2%	52	7 5%	26	3 8%	20	2 9%	0	0 0%	2	0.3%	0	0 0%	9	1.3%	689
HCOHO 1 +	13	92 9%	1	7 1%	0	00%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	0	0.0%	14
HSTS 1 +	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	1	100 0%	0	0 0%	0	0.0%	1
WCH 0+	299	90 9%	10	3 0%	10	3 0%	4	1 2%	0	0 0%	0	0.0%	0	0 0%	6	1.8%	329
WCOHO 0+	7	100 0%	0	0 0%	0	00%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0.0%	7
WSTS 1 +	9	100 0%	0	0 0%	0	00%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	0	0 0%	9
(X2 = 17 86 0 95 >P< 0 975)																	



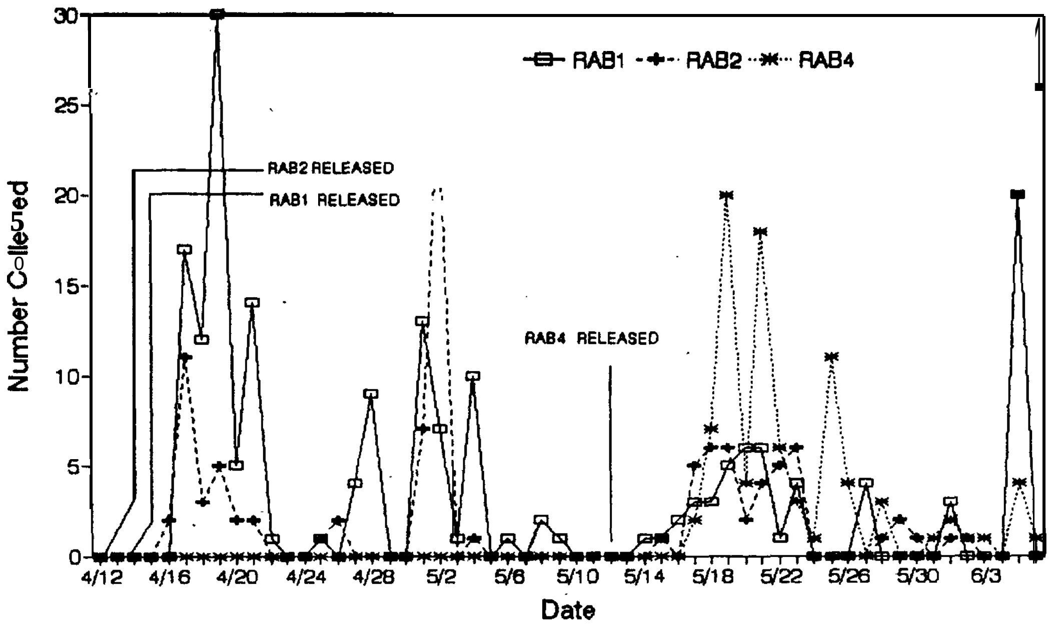
Appendix Figure A-l. Migration patterns of brand groups of spring chinook salmon from Umatilla Hatchery and Bonneville Hatchery and collected at Feed and West Extension canals, Umatilla River, March - May 1995.







Appendix Figure A-2. Migration patterns of brand groups of subyearling fall chinook salmon from Umatilla Hatchery and collected at West Extension Canal, Umatilla River, May - June 1995.



Appendix Figure A-3. Migration patterns of brand groups of summer steelhead from Umatilla Hatchery and collected at West Extension Canal, Umatilla River, April - June 1995.

APPENDIX B

Environmental and Hydraulic Parameters at West Extension Canal

Appendix Table B-l. Observations of environmental and hydraulic parameters at West Extension Canal, Umatilla River, 30 March - 30 September 1995. Secchi depth is measured in meters.

Date	River[a] flow	Debris[a]	Turbidity[a]	Water color	Canal' elevation	Secchi[c] depth
3/30	MH	L	L	Clear green	404.50	--
3/31	M	VL	VL	Light green	404.45	--
4/1	M	VL	ML	Green	404.50	--
4/2	M	VL	L	Light Green	--	--
4/3	M	VL	L	Light Green	404.35	--
4/4	M	N	VL	--	404.20	--
4/5	M	M	M	Green	404.20	--
4/6	M	M	M	Green	404.40	--
4/7	M	--	M	Dark Green	404.35	--
4/8	MH	L	MH	--	404.30	--
4/9	H	MH	H	Chocolate	404.25	--
4/10	M	L	M	Light Green	404.20	--
4/11	M	M	M	Light Green	404.20	--
4/12	MH	MH	--	Dark Green	--	--
4/13	MH	MH	M	Dark Green	--	--
4/14	MH	L	--	Light Brown	--	--
4/15	MH	L	L	Light Green	404.20	--
4/16	M	L	L	Light Green	404.15	--
4/17	M	L	M	Light Green	404.10	--
4/18	--	VL	M	Green	--	--
4/19	M	L	L	Light Green	404.20	--
4/20	M	L	L	--	404.20	--
4/21	M	VL	VL	Light Brown	404.20	--
4/22	--	--	--	--	--	--
4/23	--	--	--	--	--	--
4/24	M	L	M	Green	404.20	1.15
4/25	L	VL	VL	--	--	--
4/26	M	VL	VL	--	404.20	1.10
4/27	M	VL	VL	--	404.35	1.15
4/28	MH	M	MH	Chocolate	404.35	0.15
4/29	M	MH	H	Chocolate	404.20	--
4/30	--	M	MH	Chocolate	404.20	0.07
	H	H	H	Dark Chocolate	404.20	0.09
5/2	--	MH	H	Chocolate	404.20	0.09
5/3	H	L	H	Dark Chocolate	404.20	0.13
5/4	H	H	H	Dark Brown	404.25	0.13
5/5	MH	M	MH	Light Brown	404.20	0.13
5/6	H	L	M	Brown	--	0.07
5/7	HF	H	H	Dark Chocolate	404.20	0.07
5/8	HF	H	H	Dark Brown	404.20	0.09
5/9	H	H	H	Dark Brown	404.20	0.10
5/10	H	MH	MH	--	--	0.10
5/11	H	MH	MH	--	404.20	0.10
5/12	H	H	H	Chocolate	404.25	--
5/13	MH	MH	M	Light Brown	404.25	0.04
5/14	MH	M	MH	Dark Brown	404.10	0.05

Appendix Table B-l. Continued.

Date	River[a] flow	Debris[a]	Turbidity[a]	Water color	Canal[b] elevation	Secchi[c] depth
5/15	MH	L	M	Light Brown	404.20	0.20
5/16	MH	M	MH	Brown	404.20	0.20
5/17	M	ML	M	Light Brown	404.15	0.25
5/18	M	L	L	Light Brown	404.20	0.33
5/19	M	VL	VL	Light Brown	404.15	0.38
5/20	M	VL	VL	Light Green	404.10	0.39
5/21	--	VL	VL	Clear	404.15	0.45
5/22	L	VL	VL	--	404.15	0.58
5/23	ML	VL	VL	Light Brown	404.15	0.58
5/24	ML	VL	L	Light Brown	--	0.65
5/25	L	VL	L	--	404.10	--
5/26	L	L	VL	Light Tea	404.25	0.90
5/27	L	L	L	--	404.20	0.88
5/28	L	L	L	--	404.20	1.14
5/29	L	L	VL	Light Green	404.15	1.07
5/30	--	VL	VL	Light Green	404.05	1.07
5/31	L	VL	VL	Light Green	404.10	1.05
6/1	VL	VL	VL	Clear	404.15	0.73
6/2	ML	VL	V	--	404.30	0.91
6/3	ML	VL	VL	Clear	404.35	1.00
6/4	ML	VL	VL	Clear Green	404.40	0.90
	L	VL	--	Clear	404.35	0.77
6/6	L	VL	VL	Light Green	--	--
6/7	ML	VL	--	Clear	--	1.13
6/8	L	VL	--	Clear	--	1.00
6/9	L	ML	--	Clear	--	1.05
6/10	L	L	VL	Light Green	--	--
6/11	--	--	--	--	--	--
6/12	--	--	--	--	--	0.80
6/13	--	--	--	--	--	0.65
6/14	--	--	--	--	--	0.65
6/15	--	--	--	--	--	0.63
6/16	--	--	--	--	--	0.62
6/17	--	--	--	--	--	--
6/18	--	--	--	--	--	0.68
6/19	--	--	--	--	--	0.60
9/6	--	--	--	--	--	--
9/7	--	--	--	--	--	--
9/8	--	--	--	--	--	--
9/9	--	--	--	--	--	--
9/10	--	--	--	--	--	--
9/11	--	--	--	--	--	--
9/12	--	--	--	--	--	--
9/14	--	--	--	--	--	1.45
9/15	--	--	--	--	--	1.45
9/17	--	--	--	--	--	1.95
9/18	--	--	--	--	--	1.95
9/19	--	--	--	--	--	1.37

Appendix Table B-1. Continued.

Date	River flow[a]	Debris[a]	Turbidity[a]	Water color	Canal elevation[b]	Secchi depth[c]
9/21	--	--	--	--	--	1.35
9/23	--	--	--	--	--	1.95
9/25	--	--	--	--	--	1.67
9/27	--	--	--	--	--	1.65
9/29	--	--	--	--	--	1.55
9/30	--	--	--	--	--	1.55

[a] *F=flood, HF=high to flood, H=high, MH=moderate to high, M=moderate, ML=moderate to low, L=low, VL=very low, N=none.*
[b] *Elevation of water above sea level as measured on facility staff gauge.*
[c] *Mean depth visibility is computed from depths of disk visibility as it is lowered and raised in the water column.*

REPORT B

Umatilla River Passage Evaluation

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UMATILLA RIVER PASSAGE EVALUATION

INTRODUCTION

Five irrigation dams were constructed on the lower Umatilla River in the early 1900's (see Report A; Figure 1). Inadequate fish passage facilities at the dams presented numerous problems for juvenile salmonids migrating downstream and adult salmonids migrating upstream (Boyce 1986). The Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (1987 Section 1403, Measure 4.2) addresses passage problem corrections. New passage facilities were reconstructed at the five dams between 1988 and 1994. These facilities were reconstructed with the cooperative effort of the Bonneville Power Administration (BPA), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), various fish and wildlife agencies, and the U.S. Bureau of Reclamation (USBR). These improvements included state-of-the-art fish ladders, bypass facilities, canal screens, and at some locations, fish trapping and holding facilities.

Evaluation of these reconstructed passage facilities was recommended in *A Comprehensive Plan* for *Rehabilitation of Anadromous Fish Stocks in the Umatilla River Basin* (Boyce 1986). Evaluation of adult fish passage through the lower Umatilla River has been completed by the CTUIR (Kutchins 1990; Kissner 1992, 1993; Volkman 1994, 1995). We completed most of our evaluation of juvenile salmonid passage through the fish bypasses and ladders from 1990 to 1994 (Knapp and Ward 1990, Hayes et al. 1992, Cameron and Knapp 1993, Cameron et al. 1994, 1995). Our evaluations were modeled after and compared to studies of similar fish screening facilities on the Yakima River, Washington (Neitzel et al. 1985, 1987, 1988, 1990a, 1990b; and Hosey and Associates 1988a, 1988b, 1989, 1990). We released and recaptured marked juvenile salmonids in the fish bypasses and ladders to determine facility-caused injuries and travel time. We determined the efficiency of canal fish screens in excluding fish from the canal and measured water velocity in front of the screens to determine compliance with agency criteria for the protection of salmonid smolts and fry.

In this report we describe studies conducted to complete our original work plan and follow up studies prompted by results of the passage evaluation. We completed our original work plan by collecting water velocity measurements in front of the drum screens at West Extension Canal.

Previous studies identified Three Mile Falls Dam a passage problem for juvenile salmonids migrating through the lower Umatilla River (Cameron et al. 1994). Tests indicated subyearling fall chinook salmon are significantly ($P < 0.10$) injured when they pass through the fish ladder. In addition, yearling and subyearling chinook salmon passage is delayed by a diffuser in the ladder that diverts adult fish into a trap (Cameron et al. 1994, 1995). We set up an underwater video camera to record the behavior of fish encountering the diffuser to assess whether the diffuser delays or injures fish. We also measured velocities at similar downstream diffuser panels on the auxiliary water portion of the ladder to assess whether velocities exceeded criteria for juvenile fish.

Juvenile salmonids are able to safely pass Three Mile Falls Dam through the bypass system at West Extension Canal (Hayes et al. 1992, Cameron and

Knapp 1993). However, information on the ability of the bypass to attract and pass juvenile fish (collection efficiency) is limited. Evidence suggests that a substantial proportion of juvenile salmonid migrants use the fish ladder as a passage route rather than the bypass. Concurrent passage counts at both the ladder and bypass over a sixteen day period in late April and early May 1992 indicated nearly twice as many juvenile salmonids passed through the ladder than through the bypass (Cameron and Knapp 1993). However, in 1990 and 1991, counts of juvenile salmonids passing the ladder viewing window throughout most of the outmigration suggest that juvenile salmonids may not use the ladder as extensively as the 1992 concurrent counts indicated (Hayes et al. 1992, Cameron and Knapp 1993). Fishery managers requested us to conduct additional studies to evaluate how river flow and passage facility operations affect the collection efficiencies of the bypass for salmonid species. We marked and released different species two miles upstream of Three Mile Falls Dam throughout the migration and recaptured them at the bypass to estimate collection efficiency of the bypass during varying river flows and canal operations.

Implementation of the Phase I water exchange project in 1994, where water from the Columbia River is pumped into West Extension Canal during low flow in the Umatilla River (USBR and BPA 1989), has heightened the concern that the bypass may be ineffective at attracting juvenile salmonids. Fish attraction at the canal headgates is expected to decline when canal withdrawal is curtailed during Phase I pumping. Phase I pumping usually coincides with the outmigration of wild and hatchery subyearling fall chinook salmon which are most susceptible to injury if they select the fish ladder as a passage route instead of the bypass. There are several potential modes of operation for the bypass during Phase I pumping that may affect water currents and attraction flow at the headgates. We measured water velocity near the headgates and at key locations within the bypass to assess the fish attracting potential of the various bypass operations. These included operation of pumpback pumps singly, in tandem, or not at all, and three openings of the river-return drain pipe.

STUDY SITES

Collection efficiency tests for determining passage efficiency were conducted at the bypass facility at West Extension Canal. Flow velocities were collected at the West Extension Canal bypass facility and the east-bank adult fish ladder at Three Mile Falls Dam. Video activities were conducted at the east-bank ladder.

General description of the West Extension Canal screening facility and bypass is presented in Report A. The east-bank ladder at Three Mile Falls Dam incorporates both passage and auxiliary water sections to the total ladder structure and a high- and low-flow entrance gate (Figure 1). The ladder is approximately 150 feet long from exit to entrance and operates with a pool-to-tailrace head differential of about 10 ft. The passage portion provides a route for fish migration; the auxiliary water portion increases flow through the fish entrance to attract adult fish. Only one of the two fish entrance gates is open at any one time. Diffuser panels within the ladder guide adult fish (Figure 1). Diffuser 1 (D-1) is constructed of 0.25-inch-wide x 1.5-inch-deep metal slats arranged vertically one inch apart; horizontal cross bars are spaced 3.5-inches apart (Figure 1). In 1994, alternate horizontal rods were removed from D-l to increase the open area and reduce potential juvenile fish injury. Diffuser 1 prevents fish escape from the ladder and guides fish into the steeppass. Diffuser 2 (D-2) is comprised of two equal-sized panels of similarly constructed metal slats located at the interface of the auxiliary water system and ladder entrance pool. This diffuser functions to block adult fish from the auxiliary water section. Flow baffles upstream of D-2 create more uniform flow through the diffuser panel which reduces fish attraction to this area. Diffuser 3 (D-3) is similar in construction to D-l and D-2 and guides adult fish through the viewing window.

METHODS

Passage Efficiency

Passage efficiency at the West Extension Canal was determined by conducting trap efficiency tests for different races or species of salmonids under various canal operations from late March to July (see Report A).

We used linear correlation to determine trap efficiency relationships with canal diversion rate or river flow. We also investigated the relationship of total fish collection with canal flow using correlation.

Velocity

We measured water velocity (fps) in front of the drum screens at West Extension Canal to assess whether they met screening criteria for juvenile salmonids, developed by the National Marine Fisheries Service (NMFS 1989, 1990). Measurement transects were located at 25%, 50%, and 75% of the screen length and at 20%, 50%, and 80% of the water depth. We collected a full and partial set of measurements during sampling operations (5-cfs bypass flow) when canal checkgates were closed on 19 June 1995. Measurements were collected at all sampling depths and transects when pumpback Pump 2 was on. Partial measurements were collected at the middle screen transect when the river-return pipe was 20% open.

We measured water velocity at the trashracks, headgates, screen forebay, bypass channel entrance, and traveling screen at West Extension Canal on 3 and 4 October 1995. Velocities were measured during operations of the pumpback bay when canal checkgates were closed. We varied pumpback operations to assess velocity changes relative to fish attraction potential and to ascertain compliance with velocity criteria at the traveling screen. Pumpback operations included both pumps off. one pump on (Pump 2), both pumps on, and river-return pipe openings of 20%, 30%, and 40%. (Pipe openings of 20%, 30%, and 40% corresponded to raising the river-return pipe gate 5-inches, 7-inches. and g-inches). The bypass was operated in a 5-cfs sampling mode and canal elevation was 404.3 ft above sea level when measurements were taken. Each of the three headgates was 5-inches open during all pump operations and were progressively raised as river-return pipe openings were increased to maintain the headworks elevation at 404.3.

Water velocity was measured three to six inches in front of the traveling screens at West Extension Canal at 20%, 50%, and 80% of water depth along three vertical transects. Transects were located at the screen mid-line, and 12 inches from the upstream and downstream edges of the traveling screen.

We measured water velocity directly downstream of the canal trashracks within each channel underneath the trashrack walkway. At the headgates, we measure directly upstream of each of the three headgates and in the middle. In the screen forebay (between Screens 2 and 3) and bypass channel entrance, we collected measurements near the middle of the channel. Measurements were collected at 50% of water depth at the trash racks, headgates, and screen forebay, and at 20%, 50%, and 80% of water depth at the bypass channel entrance.

We measured water velocities in front of the two entrance pool diffusers in the east-bank ladder at Three Mile Falls Dam to document physical conditions encountered by migrating smolts. Measurements were taken in front of Diffuser 2 on 21 and 22 November 1995. Measurements were taken about six inches in front of each panel at 20%, 50% and 80% of water depth along three vertical transects. Transects were located at 25%, 50% and 75X of the screen length.

All velocities were measured with a Marsh McBirney (Model 2000) electromagnetic flowmeter. The meter was operated in a fixed averaging mode and five readings were averaged at each sampling location. At each sampling location, we positioned the flow meter sensor probe parallel to the water surface and pointing into the vector of maximum velocity. We used a thin rod with flagging to determine the maximum velocity vector for screen measurements at 20% of water depth and fish attraction measurements at 50% of water depth. The maximum velocity vector was determined with instantaneous velocity reading at 50% and 80% of water depth at drum screens. For traveling screen measurements at 50% and 80% of water depth and all depths at Diffuser 2, the maximum velocity vector was located by rotating the probe until the force of the water current on the probe assembly was minimized. To measure the angle of maximum velocity to the screen. we attached a modified protractor to the meter pole (Cameron et al. 1995).

We used trigonometric functions to calculate water velocity perpendicular (approach) and parallel (sweep) to screens. Water velocities measured to assess fish attraction potential were not converted to approach and sweep components. Approach and sweep velocities were calculated from the measured velocity and the measured angle converted to radians such that

$$\text{sweep velocity} = \text{COS}\left[\frac{\pi}{180}(\Theta)\right](V)$$

and,

$$\text{approach velocity} = \text{SIN}\left[\frac{\pi}{180}(\Theta)\right](V)$$

where

COS = Cosine function,

SIN = Sine function,
π = constant PI (3.14),
Θ = angle of maximum flow to screen face (in degrees), and
V = water velocity measured.

We computed total flow (cfs) through the screens from velocity measurements. Flow through each screen was calculated as the product of mean screen approach velocity, screen length (seal to seal), and effective screen height.

Video

We deployed an underwater video camera to record passage problems of juvenile salmonids moving through the east-bank fish ladder at Three Mile Falls Dam. We focused our efforts on documenting the behavior of yearling and subyearling fish when they encounter the midchannel diffuser (D-l). A Sony (model HMV-352) underwater video camera (equipped with a Sony model WPC-140 water proof case and 3.7 mm lens) and Sony (model EV-A50) 8-mm video cassette recorder recorded a 105^{o} field of view. A charge coupled device (CCD) detector at the camera focus permitted image detection at a light intensity of 0.7 lux or greater. We positioned the camera upstream of the diffuser using a deployment device described by Cameron et al. (1995). The device would allow viewing of any portion of the diffuser panel. Water clarity limited camera positioning and field of view.

RESULTS

Passage Efficiency

Operations at West Extension Canal were variable throughout the irrigation season due to switching between Phase I pump exchange and total river withdrawal. From late March to late May, canal flow was taken from the river (Figure 2). Rate of canal diversion, based on total river flow, ranged from 0.1% at startup to 24% at the end of May. As river flow dropped in late May, Phase I pump exchange was initiated and continued until 1 July (Figure 2). At this time, diversion rate was almost nil. At the bypass facility, the river-return pipe was closed to attract less adult fish and one of the pumpback pumps was operated to increase water velocity at the bypass channel entrance. On 2 July, nearly all river flow was diverted into the West Extension Canal (Figure 2).

Most efficiency estimates for bypass collection were conducted during the initial phase of canal operation when river flow was diverted (Figure 3). Efficiency tests for subyearling fall chinook salmon were conducted into the Phase I exchange period and these fish responded to the change in canal operations. Trap efficiency estimates for subyearling fall chinook salmon prior to 1 June ranged from 0.255 to 0.628 (Report A, Table 5). Efficiency estimates decreased to 0.044 on 1 June and ranged from 0.013 to 0.285 up to 11 June.

Linear correlations between canal flow and fish passage or between diversion rate and fish trap efficiencies varied by species and were usually not strong. Magnitude of canal flow (cfs) was weakly correlated with total fish passage through the facility (r = 0.13, P = 0.26). The rate at which canal water was diverted in relation to total river flow (diversion rate) was more significantly correlated to trap efficiencies for yearling coho salmon and subyearling fall chinook salmon (r = 0.54, P = 0.01; r = 0.50, P = 0.04) than to yearling chinook salmon trap efficiencies (r = 0.28, P = 0.15). Trap efficiencies for summer steelhead were negatively correlated with diversion rate and were not significant (r = -0.43, P = 0.39).

Extreme river flow appeared to affect trapping efficiency at the canal bypass, but linear correlations were not strong (Figure 4). When river flow exceeded 2,000 cfs, trap efficiencies for most species were extremely low. Trap efficiencies for yearling chinook and coho salmon were negatively correlated with river flow (r = -0.31, r = -0.57); the correlation with coho salmon was significant (P = 0.007). Trap efficiencies for summer steelhead and subyearling fall chinook salmon were positively correlated with river flow (r = 0.55, r = 0.39); neither correlation was significant.

Velocity

Water velocities measured in front of the traveling screen at West Extension Canal met approach velocity criteria for protection of salmonid smolts (≤ 0.8 fps) during all pumpback operations tested except a 40% open river-return drain pipe (Table 1). When the drain pipe was 40% open, criteria for smolt protection was exceeded by 0.1 to 0.3 fps at all sampling depths along the upstream transect. Approach velocity criteria for protection of salmonid fry (≤ 0.4 fps) was exceeded at six of nine sampling locations when the drain pipe was 40% open, at no locations when Pump 1 was on. and at one or two locations during all other pumpback operations tested. Measurements that exceeded criteria for fry protection were predominantly located at 20% and 80% of water depth. Mean approach velocity for the entire traveling screen exceeded criteria for fry protection when the drain pipe was 40% open (0.66 fps). but met criteria for fry protection during all other operations tested.

Sweep velocities measured in front of the traveling screen met criteria (sweep ≥ 2 x approach) during all pump and drain pipe operations tested (Table 1). Sweep velocities generally decreased from upstream to downstream locations. The 5-cfs orifice plate constricted the flow and caused a back-eddy turbulence along the downstream one-third of the traveling screen during all tests. Intensity of the turbulence increased proportionately with flow through the traveling screen. Estimated flow through the traveling screen ranged from 7 cfs when Pump 1 was operated to 28 cfs when the drain pipe was 40% open (Table 1).

Approach velocity in front of the canal drum screens met screening criteria at all sampling locations when canal withdrawals were 0 and 52 cfs (Table 2). Approach velocity in front of drum screens was barely detectable when canal flow was 0 cfs and either Pump 2 was on (Table 2) or the drain pipe was 20% open (Table 3). When 52 cfs was withdrawn and Pump 2 was on, mean approach velocity was 0.12 fps (Table 4). Canal flow, estimated from measurements of approach velocity, accounted for nearly 75X of the flow at the canal gauging station. If velocity measurements are expanded to estimate readings at maximum operating canal flow, 33% of the sampling locations would not meet approach velocity criteria for fry protection (≤ 0.4 fps). All locations would meet approach criteria for smolt protection (≤ 0.8 fps) at maximum canal flow.

Mean sweep velocity at the drum screens was 0.51 fps when canal checkgates were closed and the river return pipe was 20% open (Table 3). Mean sweep velocity was 0.64 fps when canal flow was 52 fps and Pump 2 was on (Table 4). When canal checkgates were closed and only Pump 2 was on, mean sweep velocity decreased to 0.16 fps (Table 2). Sweep velocities increased with proximity to the bypass channel when canal checkgates were closed (Tables 2 and 3), but were fairly uniform among screens when 52 cfs was drawn through the checkgates (Table 4). When checkgates were closed, mean water velocity at the bypass channel entrance was higher when the drain pipe was 20% open (1.98 fps; Table 3) than when Pump 2 was on (1.10 fps; Table 2).

Water velocities that potentially attract and move fish through the bypass facility were affected by the varying pumpback operations and closure of the canal checkgates. Water velocities at the trash racks and headgates increased when the drain pipe opening was increased from 20% to 40% (Figure 5). In contrast. water velocities at the trash racks and headgates remained uniformly low (≤ 0.17 fps) when any combination of pumps were on or off. Water velocities at the trash racks and headgates during drain pipe operations were more than three times greater than water velocities during pump operations. In the screen forebay and at the bypass channel entrance, water velocities increased proportionately with the number of pumps and diameter of drain pipe opening. Although, water velocities were nearly equivalent between a two-pump operation and a 20% drain pipe opening.

Turbulent water existed in front of D-2 at the east-bank ladder at Three Mile Falls Dam. Flow direction approaching the diffuser was variable among the sampling locations (Figure 6). Most turbulence was in front of the east panel where flow was parallel to the diffuser. creating a sweep velocity exceeding 1 fps at four locations. In contrast. flow approached the west panel more perpendicular than at the east panel. Mean approach velocity was correspondingly higher at the west panel (0.92 fps) than at the east panel (0.47 fps). Maximum approach and sweep velocities measured at Diffuser 2 were 1.90 fps and 1.61 fps, respectively.

Video

We tested the underwater video equipment inside the fish ladder at Three Mile Falls Dam on 6 April 1995. We determined the maximum field of view and optimum camera angle that could be used at Diffuser 1 under the existing lighting and turbidity. Late afternoon shadows encompassed the viewing area and Secchi disk visibility was 2 ft. Therefore, we were limited to a sharp image of 2.2 ft^2 of the diffuser. A viewing angle of 20% upward from horizontal provided defined objects in the water column the best. After about three hours under water, the camera developed a light fog inside the water-proof case.

On 7 April, we packed silica desiccant pellets in the camera housing and deployed it in front of D-1 in the late afternoon. We programmed the video cassette recorder to record cycles of twenty minutes on and two hours off during daylight hours. This programming cycle required only one tape change per day. On 8 April, we discovered a camera failure prior to the first recording (less than 16 hours post-installation).

DISCUSSION

Passage Efficiency

On 25 May, withdrawal at West Extension Canal was reduced (96 cfs) and partial pump exchange into the canal began. By 31 May, only 1.6 cfs of water was being diverted from the river with pump exchange providing most canal flow. During this time, the river-return pipe was open. shunting 20 cfs of bypass flow into the river and creati-ng good attraction velocities (near 0.5 fps) at the canal headgates. Trap efficiencies for subyearling fall chinook remained near 55%. On 1 June, we closed the river-return pipe to attract less spring chinook adults at the outlet and activated pumpback Pump 2. Headgate velocities dropped to near 0.1 fps and trap efficiency for that day plummeted to < 0.05. Phase I pump exchange and concomitant operations at the canal forebay can reduce fish routing around the dam. However, given the proper operating conditions, the bypass can route subyearling fall chinook salmon around the dam effectively.

On the morning of 3 June, we observed large numbers of subyearling fall chinook salmon migrants passing the dam via the passage portion of the ladder. During 5 minutes of observation, an estimated 300 - 500 fish per minute passed the viewing window. Water current patterns upstream of the ladder intakes appeared to affect subyearling movement. Fish were repelled by turbulent upwellings from the front of the auxiliary water intake; only 1 fish was seen passing over the auxiliary water weir.

Fish passed over the dam also. When attraction velocities were reduced at the canal headgates, fish stopped upstream of the canal trashracks. At the dam sill interface with the trashrack and debris boom, fish spilled over the dam under minimal water flow. Under such conditions. the spilled fish became stranded on rocks below.

For subyearling fall chinook salmon, passage past Three Mile Falls Dam can be very difficult and harmful under the operating and flow conditions that generally exist when they migrate. The preferred route for safe passage is through the west-bank bypass. Fish are injured by moving through the east-bank ladder (Cameron et al. 1994, 1995). However, improving passage for juvenile salmon may reduce passage effectiveness for adult salmon.

Fish species responded differently to various flow parameters, as indicated by their trap efficiency correlations. Summer steelhead exhibited a a positive correlation to river flow, but a negative correlation to diversion rate. In contrast. yearling coho and chinook salmon trap efficiencies exhibited negative correlations to river flow, but positive correlations to diversion rate. The subyearling fall chinook salmon trap efficiencies were positively correlated to both river flow and diversion rate. Differences in fish behavior, fish size, smoltification level, or flow conditions at the time efficiency tests were conducted may account for the dissimilarity in relationships.

Velocity

Although opening the river-return drain pipe can attract fish at the canal headgates, and produce good sweep velocities at the drum screens and approach velocities at the bypass channel entrance, excessive opening of the pipe (40%) creates hydraulic conditions under which velocity criteria for juvenile salmonids is exceeded. The operational design of the system is to shunt 20 cfs of bypass flow to the river or canal when only 5-cfs flow is desired further down the bypass. We estimated that a 40%open pipe passes 28 cfs of bypass flow, which is above design criteria. At times, operators have fully opened the pipe to sluice silt from the pumpback bay, killing small fish (Hayes et al. 1992).

Under normal operating conditions, (i.e. canal withdrawal > 50 cfs, pumpback pumps operating, and headworks elevation at 404.1 ft), design criteria was mostly met at the West Extension facility. The exception being several high velocity spots on the traveling screen (> 0.40 fps) when both pumpback pumps were operating. Phase I pump exchange has changed the hydraulic environment to preclude normal operating conditions at certain times of the year. Once the canal checkgates are closed, the facility can no longer operate as an effective bypass system. Sweep velocities at the drum screens and attraction velocities at the headgates become negligible. even with one pumpback pump operating. To increase effectiveness. the river-return pipe must be opened 20% to draw water and attract fish into the bypass system. But in doing so, adult salmonids can be attracted to the drain pipe terminus. This is a particular concern during late spring when river flows are low and adult spring chinook salmon are migrating upriver. Adult fish have been found holding in the drainage slough. Since adult fish passage concerns need to be balanced with juvenile fish passage concerns, options for reducing adult attraction while enhancing juvenile passage need to be considered.

The 5-cfs orifice plate is the probable cause of the back-eddy turbulence immediately upstream. It is unknown whether this reduces fish attraction and delays fish passage. Removing the orifice plate altogether may improve passage; adjusting other water control structures may help as well. Video monitoring could help us discern fish behavior at this location.

Velocities at the auxiliary water diffuser in the east-bank ladder at Three Mile Falls Dam was influenced by flow entering into the entrance pool from the passage portion of the ladder. In some locations, the excessive approach velocities could injure juvenile fish as they pass through the diffusers. Although evidence indicates that no significant injuries ($P >$ 0.10) occur at this location (Cameron et al. 1994, 1995), turbulence could be disorient fish and cause impacts on the diffuser. In many locations on the diffuser panel, measured velocities exceeded criteria for velocity through diffuser gratings for auxiliary water (0.25 - 0.50 fps; Clay 1995).

Video

Although video work in 1995 was unsuccessful, we will reattempt the video monitoring in 1996. In addition, we will attempt to assess the proportion of the migrants that use the ladder as a passage route. Video monitoring at the east-bank viewing window will be initiated in 1996.

LITERATURE CITED

Boyce, R.R. 1986. A comprehensive plan for rehabilitation of anadromous fish stocks in the Umatilla River basin. Final report of Oregon Department of Fish and Wildlife to the Bonneville Power Administration, Portland, Oregon. Contract No. DE-A179-84P18008.

Cameron, W.A. and S.M. Knapp. 1993. Pages 5-48 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Cameron, W.C., S.M. Knapp, and B.P. Schrank. 1994. Pages 5-76 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions on the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Cameron, W.C., S.M. Knapp, and B.P. Schrank. 1995. Pages 7-98 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions on the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Clay, C.H. 1995. Design of fishways and other fish facilities, 2nd edition. CRC Press, Inc., Florida.

Hayes, M.C., S.M. Knapp, and A.A. Nigro. 1992. Pages 53-103 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual and interim progress reports prepared for the Bonneville Power Administration. Portland, Oregon.

Kissner, P. D. 1992. Pages 104-139 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions on the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Kissner, P. D. 1993. Pages 49-97 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions on the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Kutchins, K. 1990. Pages 33-61 *in* A.A. Nigro, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at Three Mile Falls Dam, Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Volkman, J. 1994. Pages 77-115 *in* S.M. Knapp editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions on the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Volkman, J. 1995. Pages 99-143 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions on the Umatilla River. Annual progress report to Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, E.W. Lusty, and L.A. Prohammer. 1985. A fisheries evaluation of the Sunnyside Canal fish screening facility. Report to the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1987. A fisheries evaluation of the Richland and Toppenish/Status Canal fish screening facilities. Report to the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, E.W. Lusty, and S.J. Wampler. 1988. A fisheries evaluation of the Richland and Wapato Canal fish screening facilities. Report to the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1990a. A fisheries evaluation of the Wapato, Sunnyside, and Toppenish Creek Canal fish screening facilities. Report to the Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and G.A. Martenson. 1990b. A fisheries evaluation of the Westside Ditch and Town Canal fish screening facilities. Report to the Bonneville Power Administration, Portland, Oregon.

Hosey and Associates. 1988a. Evaluation of the effectiveness of fish protection facilities, Chandler facility evaluation. Report of Hosey and Associates Engineering Company and Fish Management Consultants to U.S. Bureau of Reclamation, Yakima, Washington.

Hosey and Associates. 1988b. Evaluation of the effectiveness of fish protection facilities, Columbia facility evaluation. Report of Hosey and Associates Engineering Company and Fish Management Consultants to U.S, Bureau of Reclamation, Yakima, Washington.

Hosey and Associates. 1989. Evaluation of the effectiveness of fish protection facilities, Roza facility evaluation. Report of Hosey and Associates Engineering Company and Fish Management Consultants to U.S. Bureau of Reclamation, Yakima, Washington.

Hosey and Associates. 1990. Evaluation of the effectiveness of Chandler, Columbia, Roza and Easton screening facilities. Report of Hosey and Associates Engineering Company and Fish Management Consultants to U.S. Bureau of Reclamation, Yakima, Washington.

NMFS (National Marine Fisheries Service). 1989. Fish screening criteria. National Marine Fisheries Service, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1990. Fish passage facilities functional design guidelines and supplemental criteria. National Marine Fisheries Service, Environmental and Technical Services Division, Portland, Oregon.

USBR (U.S. Bureau of Reclamation) and BPA (Bonneville Power Administration. 1989. Umatilla Basin Project. Initial project workplan presented to the Northwest Power Planning Council, May 1989.

Table 1. Mean velocity (fps) at the traveling screen and bypass channel entrance and flow (cfsj through the traveling screen at West Extension Canal on 3 October 1995 with one or two 10-cfs pumps or when the river-return drain pipe (RR pipe) was open 20%, 30%, or 40%. Screen measurements were collected at three depths along upstream (U), middle (M) and downstream (D) transects.

Percent of water depth	Velocity component	Pump 1 U	Pump 1 M	Pump 1 D	Pump 2 U	Pump 2 M	Pump 2 D	Pumps 1+2 U	Pumps 1+2 M	Pumps 1+2 D
		Velocity at traveling screen								
20	approach	0.34	0.21	0.11	0.52	0.24	0.17	0.47	0.24	0.33
20	sweep	0.85	0.99	0.69	1.16	1.05	0.89	1.45	1.38	1.32
50	approach	0.18	0.10	0.18	0.24	0.21	0.21	0.29	0.36	0.36
50	sweep	1.12	1.00	0.77	1.15	0.92	0.74	1.64	1.42	0.94
80	approach	0.13	0.11	0.11	0.61	0.12	0.17	0.34	0.26	0.19
80	sweep	1.24	0.93	0.78	1.31	0.94	0.65	1.92	1.36	0.65
		Velocity at bypass channel entrance[a]								
			--			1.23			1.94	
		Estimated flow (cfs) through traveling screen								
			6.9			9.6			13.3	

Percent of water depth	Velocity component	RR pipe 20% open U	RR pipe 20% open M	RR pipe 20% open D	RR pipe 30% open U	RR pipe 30% open M	RR pipe 30% open D	RR pipe 40% open U	RR pipe 40% open M	RR pipe 40% open D
		Velocity at traveling screen								
20	approach	0.45	0.42	0.30	0.40	0.76	0.69	1.11	0.74	0.54
20	sweep	1.79	1.37	0.92	2.29	1.08	1.15	2.50	1.74	1.11
50	approach	0.38	0.38	0.35	0.35	0.33	0.33	0.91	0.31	0.27
50	sweep	1.42	1.23	1.01	1.99	1.34	1.32	2.49	2.01	1.29
80	approach	0.36	0.60	0.27	0.32	0.35	0.34	1.07	0.58	0.37
80	sweep	1.87	1.29	0.99	2.59	1.42	1.36	2.51	1.80	1.50
		Velocity at bypass channel entrance[a]								
			2.07			2.46			2.69	
		Estimated flow (cfs) through traveling screen								
			16.4			18.2			27.8	

[a] *Mean velocity is based on measurements at 20%, 50%, and 80% of water depth.*

Table 2. Mean sweep and approach velocities (fps) at the West Extension Canal drum screens, Umatilla River, 19 June 1995. Measurements were collected when the canal checkgates were closed, Pump 2 was on, and 5-cfs flow was bypassed during trapping operations. Drum screens are numbered in ascending order from upstream to downstream.

Drum screen number	Transect	Sweep velocity as percent of screen submeroence			Approach velocity as percent of screen submeroence		
		20%	50%	80%	20%	50%	80%
1	Upstream	0.03	0.02	0.02	0.00	0.00	0.00
1	Middle	0.01	0.15	0.06	0.00	0.06	0.00
1	Downstream	0.04	0.03	0.01	0.00	-0.04	0.00
2	Upstream	0.01	0.07	0.06	0.00	0.00	0.03
2	Middle	0.02	0.06	0.08	-0.01	0.00	0.01
2	Downstream	0.13	0.15	0.12	-0.05	-0.02	0.03
3	Upstream	0.09	0.21	0.17	0.00	0.00	0.00
3	Middle	0.12	0.09	0.23	-0.06	0.08	0.00
3	Downstream	0.07	0.16	0.27	-0.03	0.09	0.00
4	Upstream	0.26	0.28	0.36	-0.10	-0.13	0.01
4	Middle	0.29	0.33	0.36	-0.13	0.12	0.09
4	Downstream	0.30	0.38	0.54	-0.12	0.07	0.00
Approach velocity at bypass channel entrance:					1.07[a]	1.06[b]	1.16'

[a] *Measurements collected at 20% of water depth.*
[b] *Measurements collected at 50% of water depth.*
[c] *Measurements collected at 80% of water depth.*

Table 3. Mean sweep and approach velocities (fps) at the West Extension Canal drum screens, Umatilla River, 19 June 1995. Measurements were collected when the canal checkgates were closed, river-return drain pipe was 20% open, and 5-cfs flow was bypassed during trapping operations. Drum screens are numbered in ascending order from upstream to downstream.

Drum screen number	Transect	Sweep velocity as percent of screen submergence			Approach velocity as percent of screen submergence		
		20%	50%	80%	20%	50%	80%
1	Middle	0.35	0.33	0.27	0.00	0.03	0.02
2	Middle	0.37	0.35	0.33	0.00	0.09	0.08
3	Middle	0.44	0.42	0.42	0.00	0.11	0.19
4	Upstream	0.61	0.60	0.61	0.07	0.08	0.00
4	Middle	0.66	0.59	0.68	0.08	0.10	0.00
4	Downstream	0.71	0.61	0.83	-0.07	0.12	0.10
Approach velocity at bypass channel entrance:					1.85[a]	1.94[b]	2.16’

[a] *Measurements collected at 20% of water depth.*
[b] *Measurements collected at 50% of water depth.*
[c] *Measurements collected at 80% of water depth.*

Table 4. Mean sweep and approach velocities (fps) at the West Extension Canal drum screens, Umatilla River, 27 July 1995. Measurements were collected when the canal withdrawal was 52 cfs, Pump 2 was on, and 5-cfs flow was bypassed during trapping operations. Drum screens are numbered in ascending order from upstream to downstream.

Drum screen no.	Transect	Sweep velocity			Approach velocity		
		Percent of screen submergence			Percent of screen submergence		
		20%	50%	80%	20%	50%	80%
1	Upstream	0.70	0.73	0.79	0.15	0.16	0.13
1	Middle	0.73	0.70	0.75	0.21	0.15	0.12
1	Downstream	0.61	0.68	0.73	0.07	0.12	0.10
2	Upstream	0.67	0.70	0.71	0.12	0.12	0.13
2	Middle	0.70	0.70	0.69	0.10	0.09	0.11
2	Downstream	0.57	0.65	0.66	0.21	0.06	0.07
3	Upstream	0.65	0.71	0.70	0.24	0.10	0.09
3	Middle	0.61	0.67	0.69	0.25	0.08	0.08
3	Downstream	0.58	0.62	0.64	0.15	0.07	0.17
4	Upstream	0.60	0.62	0.61	0.17	0.09	0.17
4	Middle	0.51	0.53	0.59	0.15	0.07	0.15
4	Downstream	0.25	0.33	0.54	0.06	0.07	0.07
	Approach velocity at bypass channel entrance:				1.01[a]	1.06[b]	1.13[c]

Canal flow measured at WEID gauging station by OWRD = 52 cfs
Canal flow estimated from velocity measurements = 38 cfs

[a] *Measurements collected at 20% of water depth.*
[b] *Measurements collected at 50% of water depth.*
[c] *Measurements collected at 80% of water depth.*

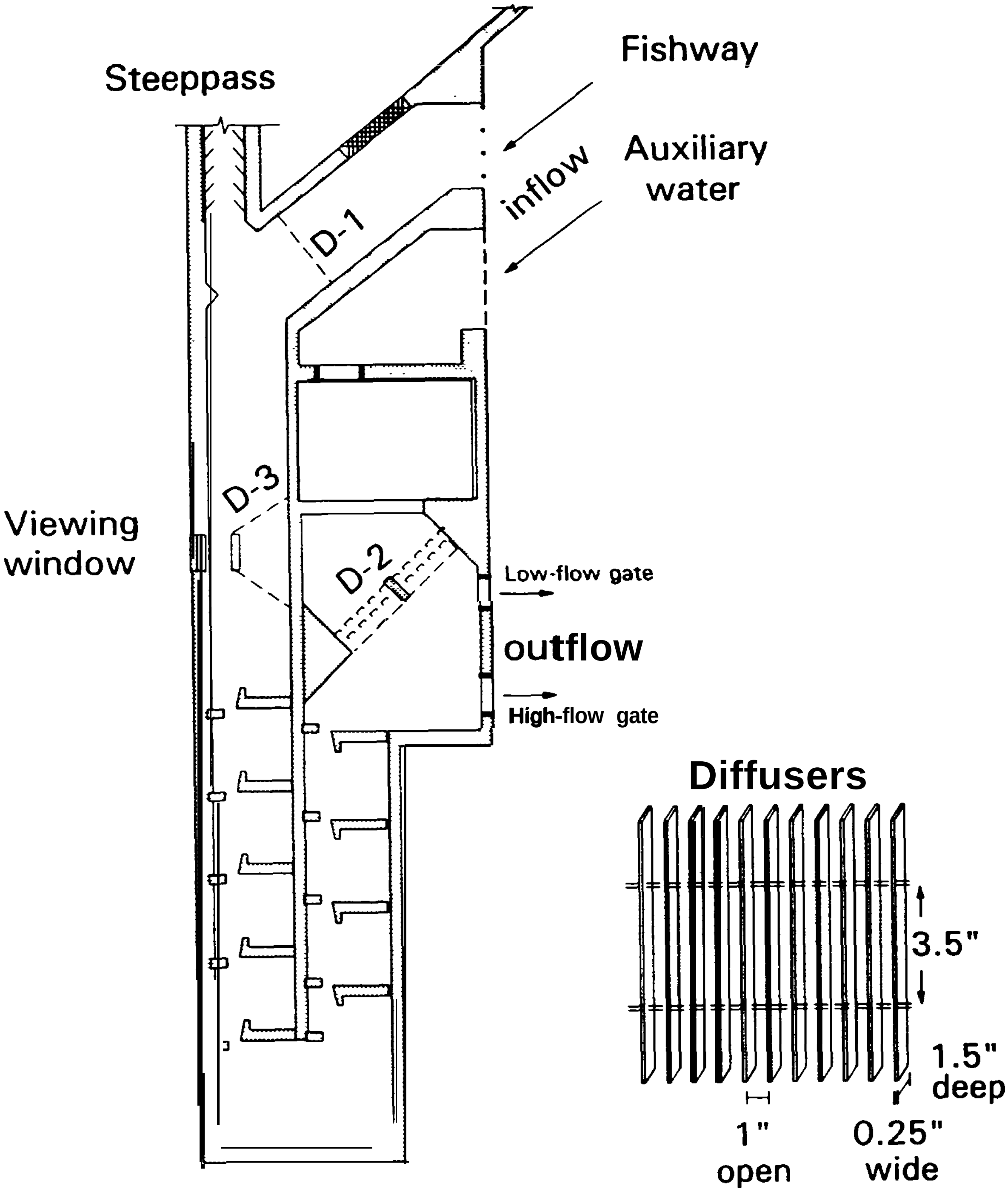


Figure 1. Schematic of the east-bank adult fish ladder and design of diffuser panels D-l, D-2, D-3 at Three Mile Falls Dam, Umatilla River.

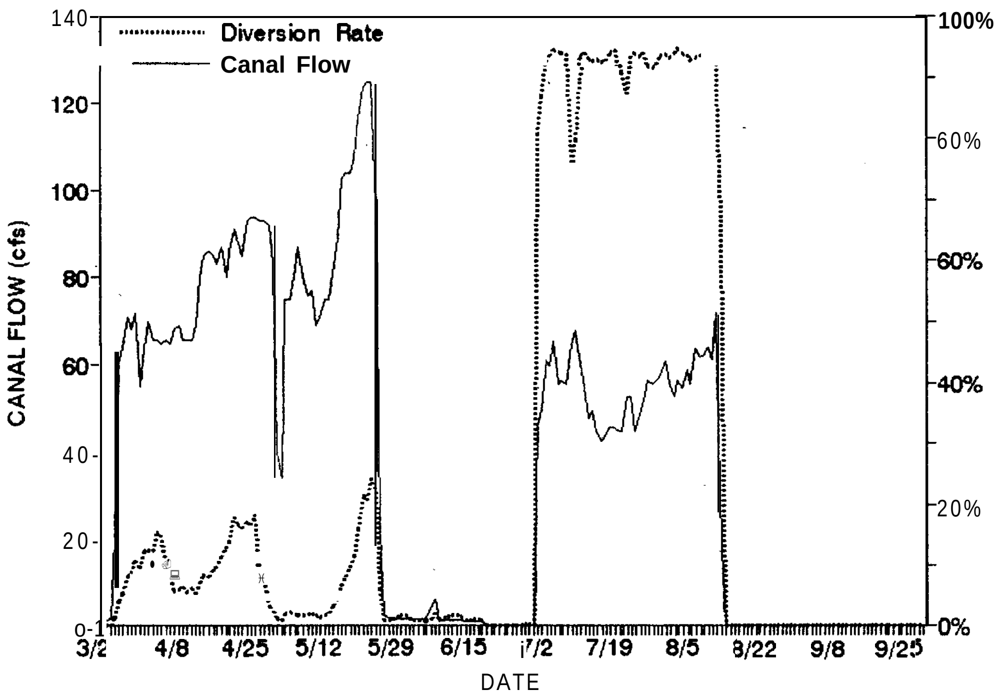
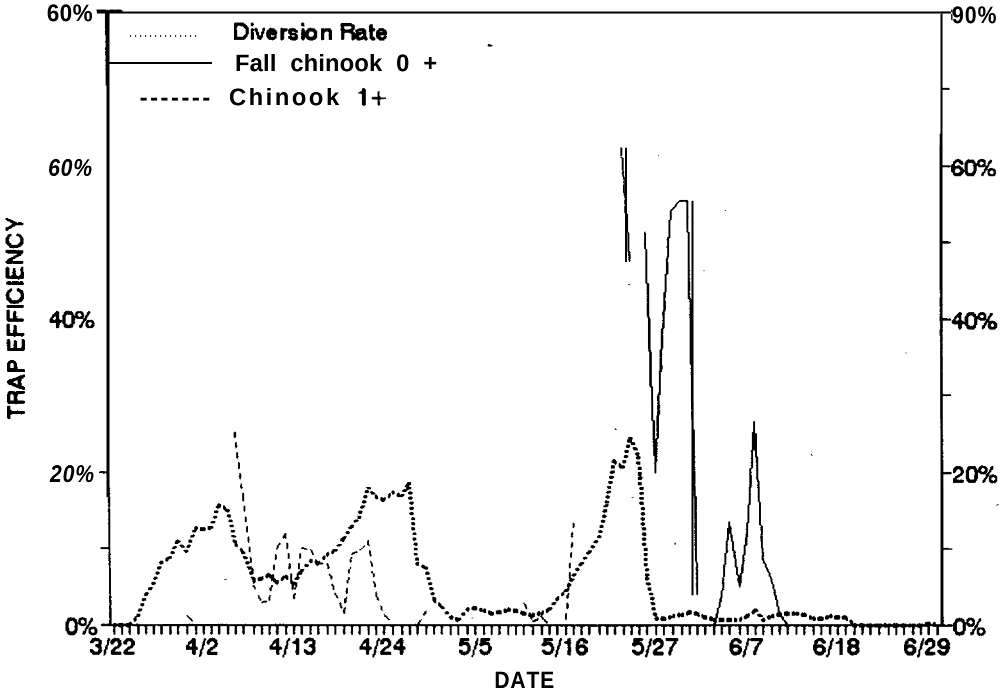


Figure 2. Canal flow and diversion rate (canal flow as a percent of river flow at RM 3) at West Extension Canal, Umatilla River, 22 March - 30 September 1995.



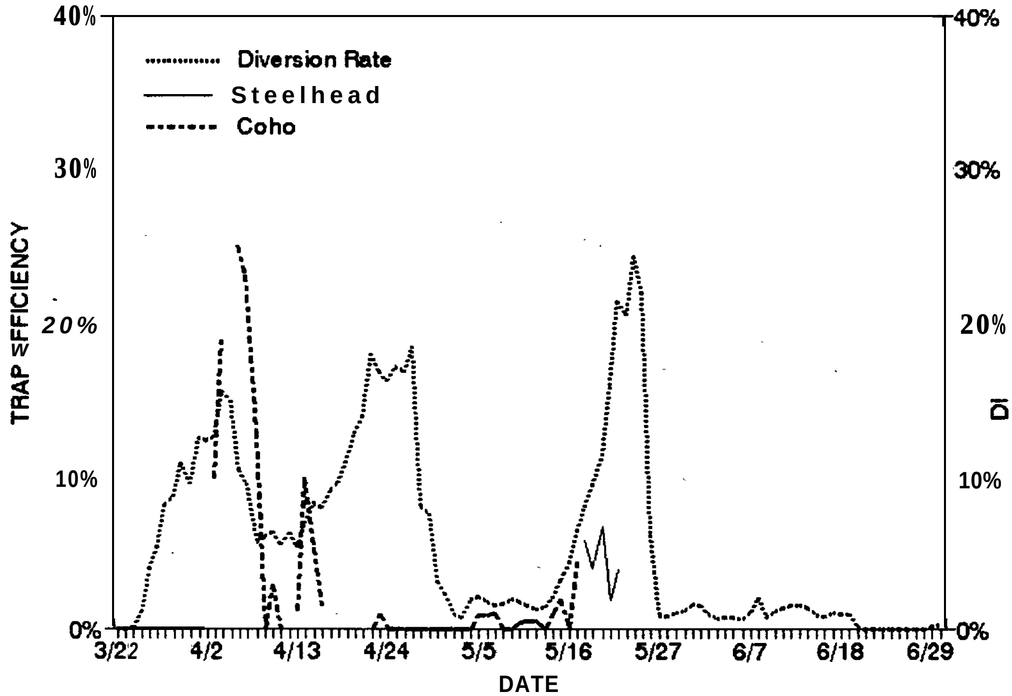
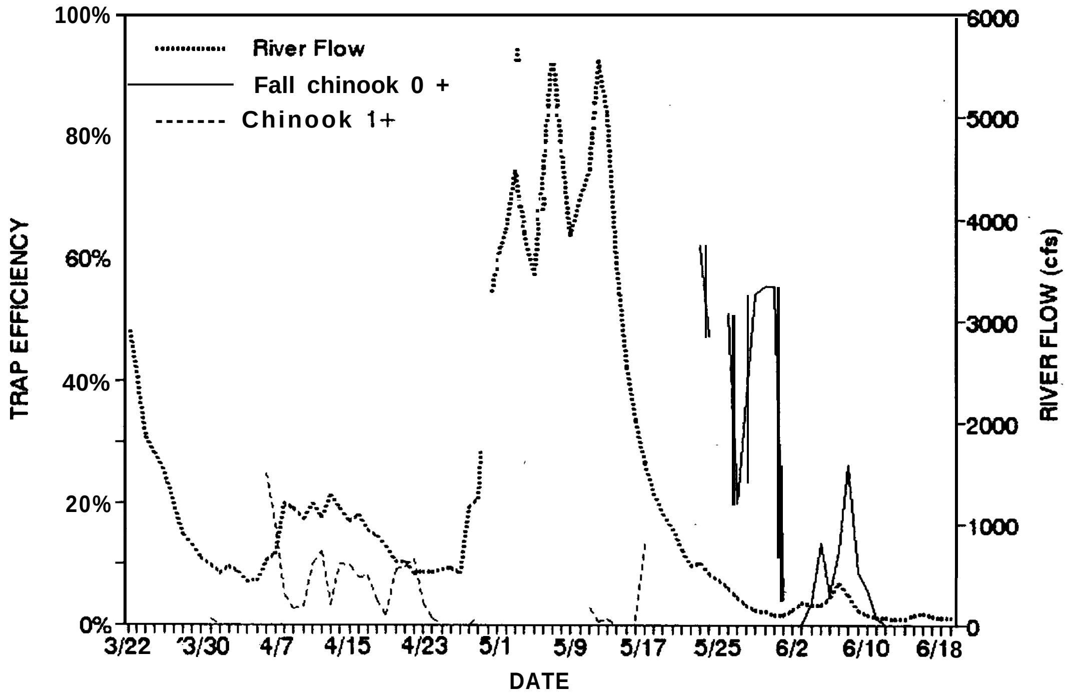


Figure 3. Canal diversion rate and trap efficiency of subyearling fall chinook salmon, yearling chinook salmon, coho salmon, and summer steelhead at West Extension Canal, Umatilla River, 22 March - 30 June 1995.



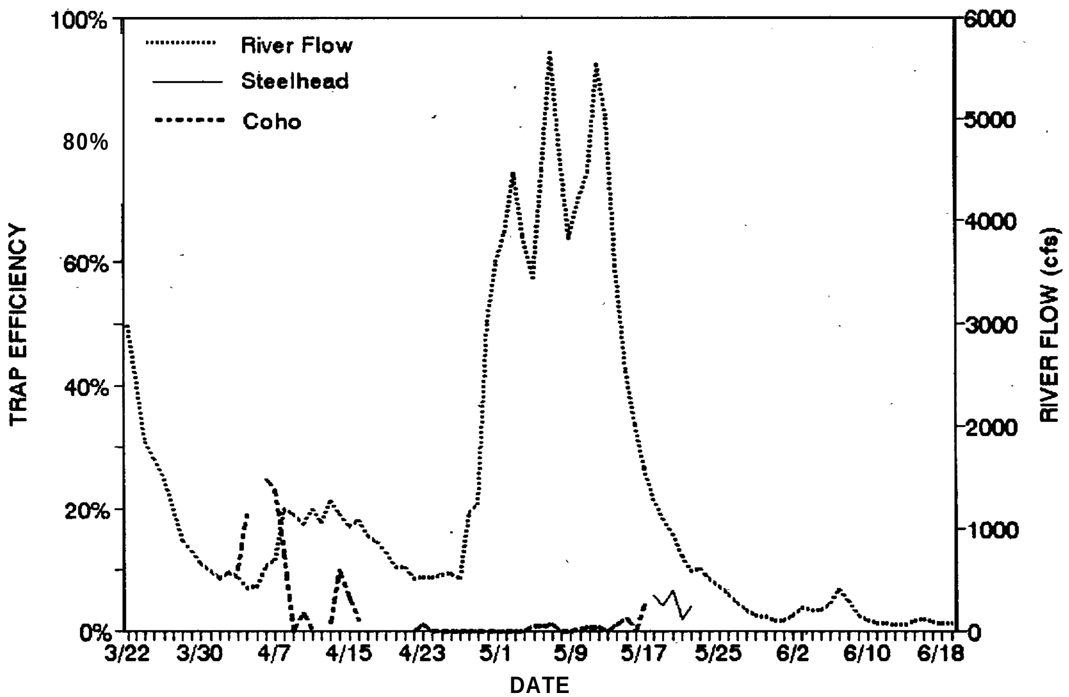


Figure 4. River flow and trap efficiency of subyearling fall chinook salmon, yearling chinook salmon, coho salmon, and summer steelhead at West Extension Canal, Umatilla River, 22 March - 20 June 1995.

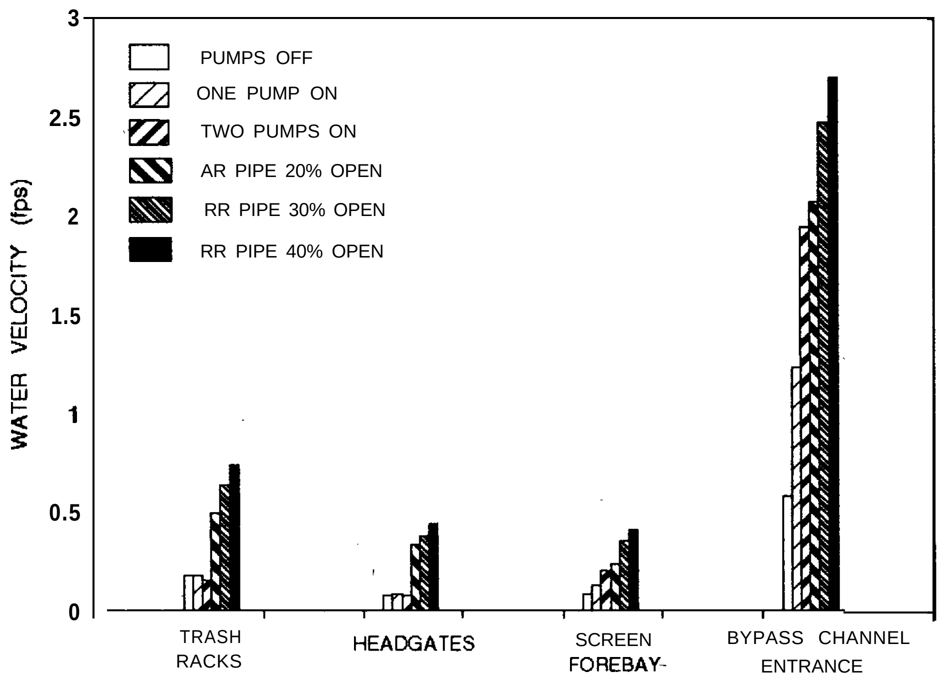


Figure 5. Water velocity (fps) at the trashracks, headgates, screen forebay, and bypass channel entrance of West Extension Canal at three pump operations and three river-return pipe (RR pipe) openings.

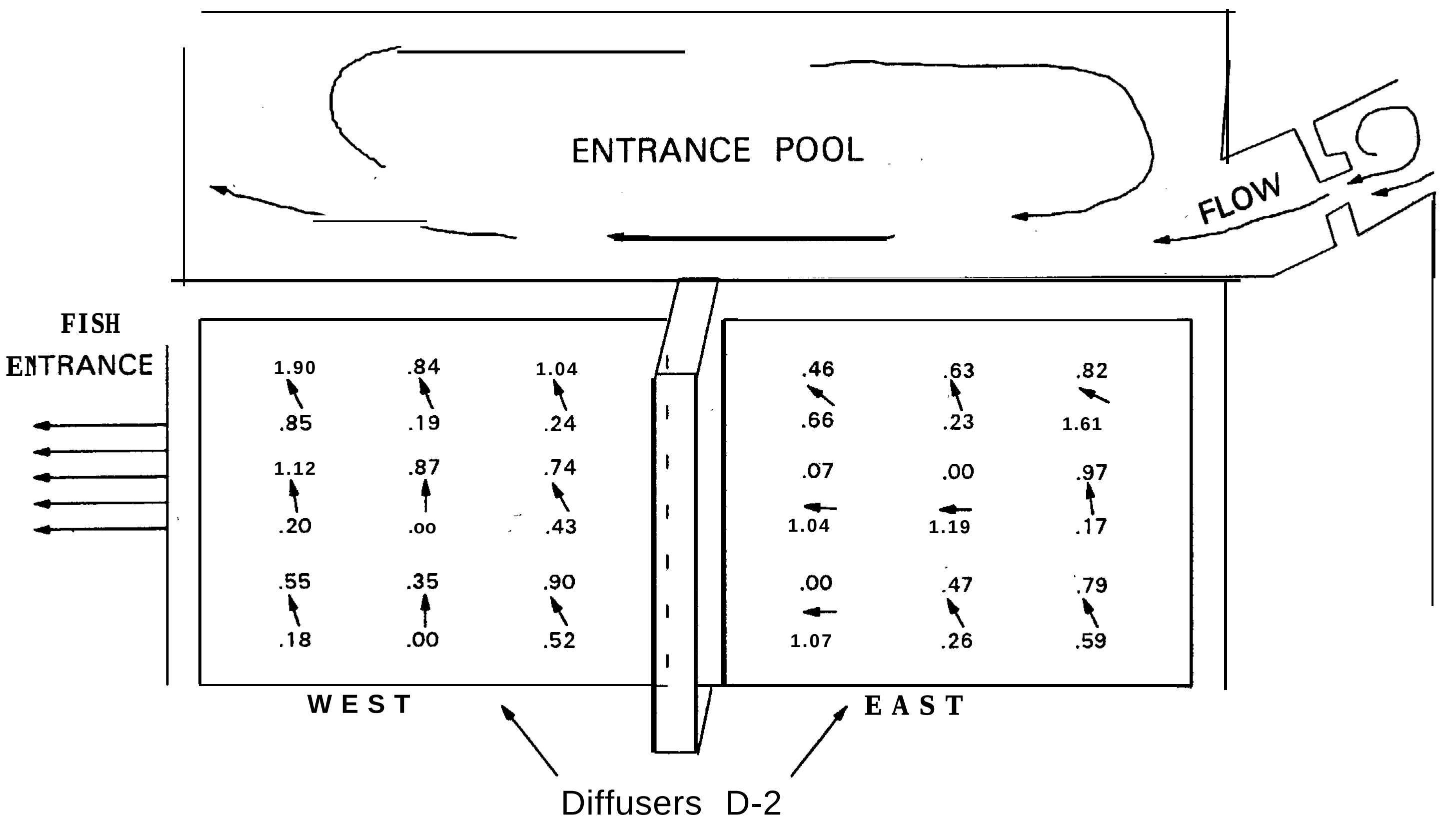


Figure 6. Approach (above arrows) and sweep (below arrows) velocity in front of Diffusers D-2 located between the auxiliary water system and entrance pool of the fish ladder at Three Mile Falls Dam, Umatilla River,- Oregon. Direction of flow is indicated by arrows. Flow perpendicular to the diffuser is depicted by arrows pointing straight up (or 1200 hours).